

# The Need for Experiments on Comets and Asteroids

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First of all, I would like to thank Academician Khariton for his kind words to all of us and to me especially. We are really sorry that he is not with us. I am glad to see all the people who are here from China, Japan, Italy, and very particularly from Russia.

Now, I would like to say a few things in a straightforward and very serious manner. I believe we are here—in fact, we all know we are here—to look into a situation that is unique in the *size* of the trouble we are looking at and in the *improbability* of these big troubles. For mathematicians, it is easy to multiply the two and to say that this trouble is like other troubles because the product is the same. For politicians who are trained to look carefully at what happens during their terms of office and less carefully at everything beyond, the same does not hold as for the mathematicians. And we, in turn, depend on the politicians to make it possible for us—in the form of dollars, or rubles, or anything else—to do what is needed to be done.

I think it is extremely important that we present a credible case so we can go ahead. I would like to suggest a few points of view on how to present the case that we are talking about—presenting it very truthfully but emphasizing the things that ought to be emphasized.

Here is the situation that, to my mind, is a scandal, and I think people can understand that it is a scandal: There is a probability of a few percent in the next century of the arrival of a stony asteroid—not the biggest possible but a fairly big one, approximately a hundred meters in diameter. It delivers on impact maybe 100 megatons. It is a practical certainty that, when and if such an object should bump into us, it will come *completely* unannounced. We won't have *any* indication of it. Yet such an object is apt, with a fairly high probability, to do a lot of damage—for instance, cause a tsunami if it falls into the ocean. Damage would be concentrated on the shores region, where people like to aggregate. So the effect of the asteroid and the people are attracted to the same meeting point—hence, a lot of damage. Just in dollars it could be billions, and in lives it might reach millions. Yet, no warning whatsoever.

What we need to rectify this situation is half a dozen arrays of charge-coupled devices and appropriate (not very big) telescopes, amounting to probably not much more than ten million dollars altogether. If such a catastrophe should occur, afterwards we'll be able to point out on existing pictures where the asteroid has approached, but we wouldn't know it ahead of time because nobody would have looked at those pictures. I shouldn't have said nobody; I should have said *hardly* anybody. And actually, to find them would be extremely difficult. The CCDs can be systematically trained to scream when there is something suspicious, and in this way we could have information a week ahead of time. To my mind, such action would correct a very large incompleteness in our safety system. And I think that should be a very salable item.

So, we know ahead of time that something is coming. What do we do about it? We would know ahead of time with sufficient accuracy, for instance, what shorelines have to be evacuated. A week is not plenty of time, but it is very considerably more than nothing.

I was interviewed today and the question was asked: Is the international situation ripe for such action? I'm answering with every confidence: It is. I have no doubt that if there is such a danger from outside, if we know that people in certain spots will have to move to save their lives and can't move to save their property, then it will be psychologically not only a necessary thing but an *easy* thing to get help from all over the world to whoever has to evacuate. I hope that the same thing holds for all the other measures that we might be willing and able to take in order to improve the situation, because I certainly don't want to stop at the point of just saying "evacuate."

The next point that I feel is a real necessity is to know what more to do. We have the power to reach out into space and to deliver what is needed. But we don't know how the objects behave that will arrive. Very particularly, we will know rather little about the actual object that has been a mere spot on the best photographic plate and that has grown for the last couple of days a little more to not very much more than a bigger spot.

What do we do about it? I claim that the next thing we ought to do is to gather knowledge about what can be done. What is the variety of things that can be done? Such knowledge can be obtained in a number of different ways. The one I prefer (and that all of us will not necessarily prefer) is to make experiments—one or two or three per year—on objects that are getting close to the Earth, to the approximate distance of the Moon, more or less one light-second away from the Earth. Whatever we do can be observed from the Earth very easily. And to get out there is not very difficult.

And what do we do there? Well, we can do a number of things. I would recommend that, to begin with, we do the very simplest thing on which we can agree: Put up sharp tungsten knives for the purpose of cutting up the incoming object if it's of an appropriate size—something like 300 feet or 100 meters in diameter. Of such objects, approximately a few approach in a year. We make experiments on them. Can every one of them be sliced up sufficiently so that if the fragments fall on the Earth, they will be burned up in the high atmosphere in a completely harmless manner? This certainly can be found out by experiments on objects that have already passed the Earth. I think such experiments will contribute, to a considerable extent, to safety in the one-percent-per-century case that such a danger might actually occur.

Now, if we find that the biggest or toughest of these objects will not be completely sliced up, then, after we have become familiar with the slicing up, we should take the big step—using a nuclear explosive. If, for instance (which I think is a plausible situation), on a 300-meter-diameter object, we have succeeded in slicing up 20 meters of the surface, we can then put a nuclear explosive close to the surface, which will irradiate the rubble that we have already created. This tends to homogenize this rubble and push it one way, while, by reaction, the remaining ninety percent of the material is pushed the other way. The reaction on the main body will be very powerful, and there can be no doubt that appropriate deflections can be arranged.

Objects a kilometer or more in diameter are apt to create worldwide disaster. On the average, they are expected once in a million years. We hope to discover them several months in advance. The use of nuclear explosives as outlined might or might not suffice to deflect them. A more radical method of using several nuclear explosives may be needed. We might use them to create the rubble, and this may be followed by one big blast as mentioned above. Or we might attempt to bore a hundred-meter-deep hole by successive nuclear explosives and then blow up the object by one big, deeply located explosion. Such methods cannot be relied upon without experimentation on objects that have safely passed the Earth.

One final possibility should be considered. Of the hundred-meter-diameter objects, there are approximately a million. They could be discovered, catalogued, and their orbits computed. If a huge, hundred-kilometer object approaches and is apt to hit the Earth within a year, then one of the hundred-meter objects is almost certain to approach it to within approximately one light-second before this can happen. Careful deflection of this smaller object could steer it into the path of the bigger one. The expected result would be to prevent a collision with the Earth, which would be the ultimate catastrophe. One must add that collision of a hundred-kilometer object with Earth is not apt to be predicted even in a billion years.

I would like to conclude with emphasizing one obvious principle: We scientists are *not* responsible and *should* not be responsible for making decisions. But we scientists are uniquely and absolutely responsible for giving information. We must provide the decision-makers with the data. On the basis of this, they will have the best chance to make the right decisions. That is the main reason why I say that we must pursue and must be given the means to pursue the knowledge as to when and how objects will arrive and the knowledge as to possible ways to deal with them. The choice of how to deal with them can be and should be delayed. If need be, it can be done and probably will be done in the last moment. But knowledge—the firm knowledge, not merely guesses on how asteroids will react but knowledge based on experiments—should become available. That is our responsibility. And I believe we should argue, in a carefully considered manner, so that we can acquire, in the most efficient manner, as much of the relevant knowledge as is possible.

I can add only two words: Good luck!