

Other-Worldly Matters

Carl Sagan in Conversation With Jayant V. Narlikar

Dr. Carl Sagan was in New Delhi late last year to deliver the prestigious annual Nehru Memorial Lecture at Teen Murti House. He also addressed the Global Forum of Spiritual and Parliamentary Leaders on Human Survival and exchanged views with friends and colleagues in the Indian scientific community. In his talks Sagan discussed the achievements of space exploration and the worrisome state of the global environment. He appealed for international cooperation to deal with such growing problems as the deterioration of the ozone layer, the buildup of greenhouse gases, and the rapid pace of deforestation. "No one nation is responsible for these problems, and no one nation can solve them," he said. "We must all work together."

Sagan is David Duncan Professor of Astronomy and Space

Sciences and director of the Laboratory for Planetary Studies at Cornell University in Ithaca, New York. He is best known for *Cosmos*, a 13-part television series that has been seen around the world (Doordarshan broadcast it a few years ago), and for the book by the same name. His wife, writer Ann Druyan, who has collaborated with him on *Cosmos* and many other projects that popularize science, accompanied him to India.

We invited Dr. Jayant Vishnu Narlikar, director of the Inter University Centre of Astronomy and Astrophysics in Pune, to conduct an interview with Sagan for SPAN. The two eminent astronomers talked about some of their favorite subjects—current space research, the origin of life on Earth, the search for extraterrestrial life, and other matters. Here is an edited transcript of their discussion.

JAYANT VISHNU NARLIKAR: I wonder if you remember 20 years ago when you had very kindly taken me to the laboratory of Dr. Bishun Khare at the department of planetary studies at Cornell University, Ithaca, New York.

CARL SAGAN: Yes, I remember. Dr. Khare and I are still working together.

NARLIKAR: You showed some of the experiments you were working on at that time. So, to begin, I want to ask you what has been going on there recently?

SAGAN: We have been extremely successful lately in simulating the atmosphere of Titan, which is Saturn's biggest moon. Peculiarly for a moon, it has a dense atmosphere and an impenetrable haze. You cannot see the surface of Titan, as we discovered in 1980-81 when the Voyager II spacecraft flew by Titan. But what we did find were a range of organic gases in the atmosphere. We found out some properties of the fine reddish particles that make up the haze of Titan.

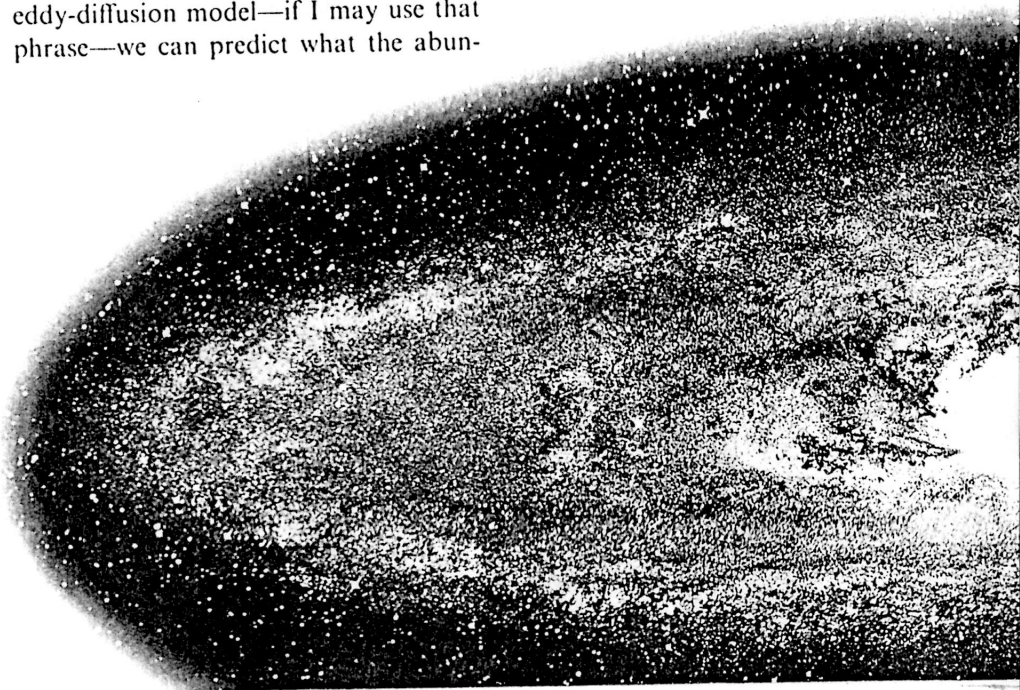
We now have completed a program in the laboratory in which we mix together the principal constituents of the Titan atmosphere—nitrogen and methane—at very low pressures and radiate them with

charged particles simulating the electrons trapped in the magnetic field of Saturn. As Titan goes around Saturn these electrons pour into its atmosphere.

What we found is that when we do this simulation we make gas-phase products, which are organic molecules built on the constituent atoms, carbon, nitrogen, and hydrogen, and that the interior of the vessel is coated with a reddish-brown powdery salt. We found that we make precisely the organic gases found in the atmosphere of Titan. With the simplest eddy-diffusion model—if I may use that phrase—we can predict what the abun-

dances ought to be, and those are the observed abundances. So, this is the first time that any planetary atmosphere has been quantitatively reproduced in the laboratory.

Now, we take the solid stuff that's coating the interior of the reaction vessel and measure what are called its optical properties. We can compare these so-called optical properties with what Voyager found by examining the clouds, and there is a beautiful match.



NARLIKAR: What kind of wavelength range have you measured?

SAGAN: We have measured the optical constants from soft X-rays to microwaves. We haven't measured Titan yet in that range, just the near ultraviolet, the visible, and the near infrared. But there it matches beautifully with what we have done in the lab.

So the next question is: What is this stuff? What is this powder made of? If we drop it in liquid water, we make a wide range of amino acids. If we examine it, we find it is an extremely rich variety of organic molecules, some quite like those that make up life, some quite different. What is especially exciting about this is the possibility that on Titan today we have a kind of model of what was happening on Earth four billion years ago—at the time of the origin of life.

Now, I recognize that there are some differences: It's extremely cold on Titan, so you would not expect to find much liquid water at those temperatures. But it looks as if cometary impact occasionally makes liquid water because of the high temperatures caused at impact. Every place on Titan has seen liquid water, at least briefly. So, we take this as a significant success.

Here for the first time is a closely accurate simulation of complex chemistry going on in the real planetary atmosphere and that gives us increased confidence that when we try to duplicate other planetary atmospheres, or when we try to

simulate the conditions on Earth at the time of the origin of life, what we are finding in the laboratory might be relevant to real circumstances.

NARLIKAR: Do you see any other places in the solar system where there could have been life?

SAGAN: We haven't said anything about life; we've just talked about organic chemistry. So, I guess the first question we have to ask is: Could there be life on Titan? And I can answer that very quickly: I don't know. There is very complicated organic chemistry there, so maybe we shouldn't entirely exclude the possibility of life. But I want to stress that there is a big difference between saying I don't want to absolutely exclude the possibility and saying I think there is life there. There is no evidence whatever of life. Now, for other worlds in the solar system—the giant planets Jupiter, Saturn, Uranus, and Neptune—all have atmospheres in which carbon-rich organic chemistry is happening. And with this Titan success behind us we are now simulating some of those worlds. Also on Triton—the big moon of Neptune, about which almost nothing was known until 1989 when Voyager II flew by it—we found an extremely thin atmosphere. The Earth's atmosphere is a lakh times denser. (I just learned what a lakh and a crore are, so I'm trying to work them into the conversation!)

So in this astonishingly thin atmosphere—it's almost a vacuum—organic matter is forming and settling on the surface. There is a different kind of or-

ganic chemistry there—ice organic chemistry, with frozen nitrogen and frozen methane. One of the beautiful things found on Triton are geysers shooting this black stuff up into the sky and then being blown by the prevailing winds at this tiny pressure, and so there are these beautiful long dark streaks on the surface. In the last five or six years we have discovered that comets have a very rich organic chemistry, 20-25 percent composed of organic molecules.

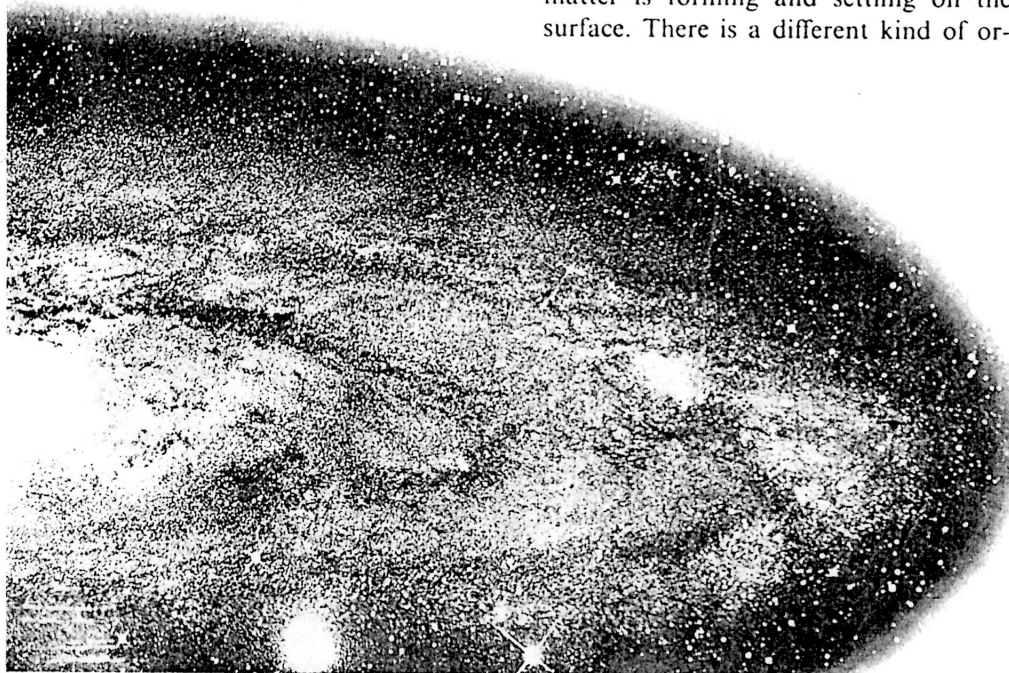
And so the question is: Could comets have made a significant contribution to the origin of life? There's no doubt that comets hit Earth on occasions, and there is no doubt that the impact rates four billion years ago were much more than today because the solar system has been cleaning itself up.

NARLIKAR: You're referring here to initiating life?

SAGAN: Exactly. When I say contribution to the origin of life I am talking about carrying the molecules from which life arises; I am not talking about carrying living organisms. Huge numbers of comets containing 20 percent organic matter slamming into Earth conceivably would deposit large amounts of organic matter. But comets travel very fast, and we have done calculations to show that the organic matter is almost all fried on entry. It just gets too hot.

But if the ancient atmosphere were ten times the pressure, as we believe it was, then our computer model shows a funny thing: There is a kind of a cap on the back of the comet that doesn't get heated very much. All the front and the interior organics get fried, but at the back there is a cap that's preserved, so that's one way in which extraterrestrial organic matter might have contributed to the origin of life.

But it turns out that there are other ways that are more efficient than this direct one. Fine cometary debris flowing into the atmosphere was much greater then, and then there is no frying because it falls very gently. The most important contribution may have been the shock waves produced by the impact, driving a



chemistry in the early atmosphere if it was hydrogen rich.

So what we have done now is to make a kind of inventory, add up all the sources of organic matter from the outside and from the inside—from inside I mean from electrical discharges like lightning, ultraviolet light from the sun—to see which sources contribute what.

The conclusions are model dependent: If the earlier atmosphere were hydrogen rich, then you make a lot of organic matter, and if it was mainly carbon dioxide, as many geologists believe, then it is not so easy to make things. And in that case, what's carried in becomes important.

This is a very quick survey of some of the recent work done in our laboratory on extraterrestrial organic matter and its possible connections to the origin of life.

NARLIKAR: My interest was fired by your book, *The Cosmic Connection*, about the SETI (Search for Extraterrestrial Intelligence) program (see SPAN, August 1991). What is the current status of the SETI program in the United States?

SAGAN: It is surprisingly healthy. I say surprisingly healthy because it is so easy to caricature and make fun of a search for extraterrestrial intelligence. Are you going to spend hard earned tax money looking for little green men when we have urgent social problems? What a waste of money! What were you thinking of?

In my view, if scientists cannot give good answers to questions like that, they shouldn't have tax money. You must be able to answer those questions. They are absolutely legitimate questions. Right now, there is a very sophisticated search program called META (Mega-channel Extraterrestrial Array). This is being carried out in the northern hemisphere at Harvard University in Cambridge, Massachusetts, and in the southern hemisphere outside of Buenos Aires, Argen-

tina, looking at more than eight million separate radio frequencies at once. And all of this is supported not by the government but by a private membership organization called The Planetary Society, of which I happen to be president. The cost for running these programs comes from \$5 and \$10 and \$15 contributions by people not only from the United States but from all over the world. This indicates first the widespread interest in SETI, and second, how inexpensive it is.

This year NASA (National Aeronautics and Space Administration) is instituting a still more sophisticated program, which doesn't yet have a good name. I think that in ten to 15 years from now—if we have not found radio signals from hypothetical civilizations on planets going around the stars—we will have learned something very important.

NARLIKAR: You can put some limits on various theories and speculations by this kind of research?

SAGAN: That's right. And, of course, if we succeed, it will be the most revolutionary discovery in history.

NARLIKAR: In that connection I wanted to mention that in India we are constructing a giant meter-wave radio

telescope (GMRT) about 95 kilometers from Pune. It will have a structure like the VLA (Very Large Array) with a Y-shaped distribution of antennas. Six antennas are fixed on each of the three arms, each arm extending several kilometers. Each dish antenna is 45 meters in diameter. I am working with my colleague, Dr. Govind Swarup, who is the brain behind this system, to use it also for SETI. I feel that this magnificent instrument could also be used part of the time to look for extraterrestrial signals.

SAGAN: There is no activity that is more appropriately international than the search for signals from another civilization. If a civilization is sending them, they're not directing their signals to any particular country.

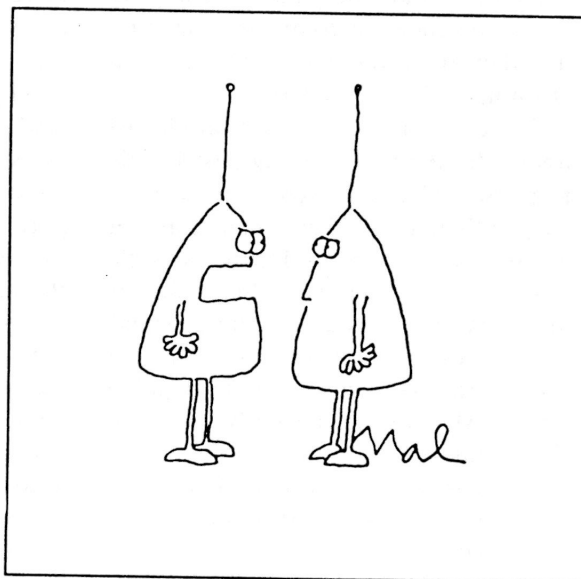
NARLIKAR: That's right, nor in any particular language.

SAGAN: If we can be of any help, please let me know. We have limited resources, but I would at least try to train anyone Dr. Swarup designates on how META works, the kind of equipment, and so on.

NARLIKAR: That would be useful. The GMRT is supposed to start working in 1994. So there are a couple of years.

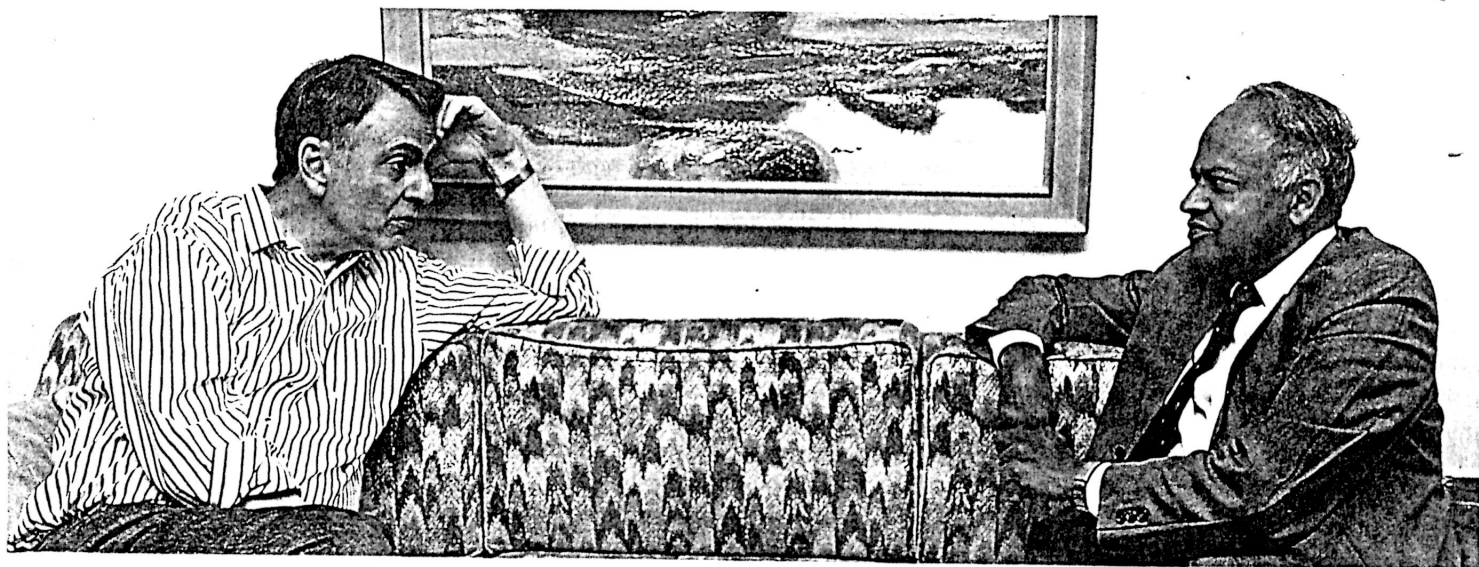
If I may change the subject slightly, you have been very active in popularizing science in various ways. The *Cosmos* series was very successful in India and I had a lot of feedback from young students asking questions. It certainly raised the awareness of astronomy considerably. What are your future plans toward popularizing science?

SAGAN: We have recently updated the *Cosmos* series. When we made it, no spacecraft had ever got close to Saturn, Uranus, Neptune, or a comet like Halley's. That is a large harvest of worlds, especially considering the moons and the rings of Saturn, Uranus, and Neptune. And that's just one example of things that needed to be added. We have been having discussions on the possibility of showing the new version in India. I am not absolutely sure, but I am optimistic that it will happen.



"Carl Sagan is beginning to get on my nerves!"

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It took two-and-a-half years of full-time work to produce the original series; I am not sure I will do such a thing again. I certainly have been writing popularizations of various kinds of science. My most recent book, which is not yet published, is written with my wife, Ann Druyan. Called *Shadows of Forgotten Ancestors*, it is an attempt to understand why human beings are the way we are. Where do ethnocentrism, xenophobia, and dominance hierarchies come from? Where does the oppression of women come from? One can see such features, I think, in Indian life, and one can see them in American life. Almost everyone deplors them, and yet they remain. So we thought it would be useful to go into the evolutionary origins of these kinds of characteristics. That's not connected very closely with astronomy, but it is an extremely important issue. So that is another example.

NARLIKAR: Whenever I give a public lecture on any topic in astronomy, people usually ask questions at the end. Some questions are directed at whatever I have talked about—for instance the big bang theory or black holes. Invariably, regardless of the topic of my talk, somebody asks about UFOs and the Bermuda Triangle. I presume you must also be getting a lot of such questions. How do you answer them?

SAGAN: Yes. In fact, I got a phone message from someone here who has a UFO he wishes to show me.

NARLIKAR: Oh, I see. It's still there, is it?

SAGAN: If I understood the message right, it's still there.

Well, I can give a quick response to these issues. On the Bermuda Triangle, there is the claim that there is a particular region of the Atlantic Ocean near the island of Bermuda in which ships and planes mysteriously disappear. Now, the first relevant fact is that sinking in water is a known physical phenomenon. So, I would compare this with, for example, disappearing trains. If there were a Pune Triangle, in which cars of the Indian Railways mysteriously disappeared, then I would say: This is mysterious. How can trains disappear? But planes and ships we know how they can disappear: They sink, and they are at the bottom of the ocean. It's not, *a priori*, a mystery.

Therefore, the question I would ask about the Bermuda Triangle is: Do the ships and planes disappear there more frequently than in other equally traveled, equally large areas of Earth? And the answer is, no. There is no Bermuda Triangle mystery. It is all a misunderstanding or, to some extent, a fraud—an attempt to make some money by deluding people who are insufficiently critical in their thinking.

As far as UFOs go, you will know from my scientific interest that no one is more interested in the possibility of an extraterrestrial life than I am. I have been involved in sending spacecraft to planets to look for life. I have been involved, as

we have just been talking, in using large radio telescopes to see if anyone is broadcasting to us. I would be very happy if we were visited. But extraordinary claims require extraordinary evidence. And in this case the evidence is not good at all. There are many anecdotes. A person can think something has happened that has not. Psychological aberrations are known in human behavior. People are also known occasionally to lie. People are known to get drunk, to hallucinate.

There have been a million UFO cases since 1947. In any of these cases, did the witness bring back an extraterrestrial artifact? A book in a strange hieroglyphic, an alloy unknown on Earth, a piece of matter that has antigravity properties? Is there anything real that you can look at? The answer is no. Not even a good photograph that couldn't be fake. And that to my mind is telling. Many cases have been reliably reported—for instance a hundred different people report a light in the sky. Well, many things can be lights in the sky. A reentering Russian or American booster can make a very spectacular light.

So again, I would say extraordinary claims require extraordinary evidence. And the evidence is simply not good enough. My mind is open if there is really a good case. But, I have learned that it is a waste of time to go and speak to one or two people who say they have had an extraordinary experience. Many of them are sincere, but it does not match the standard of scientific evidence. So I

would say to anyone who has been taken aboard a space aircraft, please bring an extraterrestrial being when you come back.

NARLIKAR: Or an extraterrestrial object.

SAGAN: An extraterrestrial being would even be better. But an object, an artifact, or whatever pets they have—anything at all would do.

NARLIKAR: Suppose you established some contact with intelligent beings. What question would you ask them, assuming they know more than we do?

SAGAN: Which almost certainly would be the case, because we can just barely communicate. I think social, economic, political, and religious questions are, in a way, much more important than the physics, mathematical, or biological questions. But still physics, mathematical, and biological questions are wonderful. I might ask: Could you please provide a simple proof for Fermat's last theorem? That's specific enough. [The theorem states that it is possible to divide a cube into two cubes, or a fourth power into two powers, or in general any power *ad infinitum* into two like powers. Fermat's proof was never found.]

NARLIKAR: My question, in that case, might be: Is the Riemann Hypothesis valid or not? [The hypothesis, still unproven, is concerned with a complex valued function, having direct application to the theory of prime numbers.]

SAGAN: Yes, things of that sort and then into more difficult issues. But where we have problems that have eluded us for centuries and where they are very well defined in mathematics—the two cases we just talked about are just that—that's where I would start.

NARLIKAR: The reason why I would choose math or physics is that the problems would be the same. But social problems, economic problems....

SAGAN: Absolutely. Who knows what they are like biologically and all of that? But anyway, I hope I have the difficulty of

trying to decide which are the most important questions. I would look forward to that. That would be a lot of fun.

NARLIKAR: You have written a lot about the threat of nuclear devastation, nuclear winter, and all of that. Do you see any relaxation in the situation now?

SAGAN: There is no question that tensions between the United States and [the former] Soviet Union have eased a lot. That is something everyone should be thankful for and both nations have made an important contribution to that. In my judgment the principal contribution has been made by Mikhail Gorbachev. I think any objective look at history will show that he is the person who had the boldness to do it. The Warsaw Pact has collapsed. There is no Warsaw Pact. Who

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would have imagined that five or six years ago? It's amazing. Nevertheless, not one nuclear warhead has been destroyed by either the United States or the Soviet Union. There are approximately 55,000 nuclear warheads still on the planet. About 25,000 nuclear weapons on hair-trigger readiness are ready to be launched. And I would hardly call the circumstances safe. I think things are safer, but they are not nearly safe enough.

NARLIKAR: Because there is the other danger of information spreading and smaller groups getting nuclear weapons?

SAGAN: I was just talking about the Soviet Union and the United States. Even there, there is still a significant danger in who is controlling the Soviet nuclear arsenal. Bear in mind that they have approximately 25,000 nuclear weapons, and a hundred are enough to destroy any nation on Earth. Or to cause nuclear winter if they are targeted effectively at cities.

Now as far as other nations, in South

Asia particularly, are concerned, yes I think that proliferation of nuclear weapons is exceptionally dangerous. As I said, the United States, the Soviet Union, Britain, France, China, and Israel having nuclear weapons is very dangerous. Even if you were to believe that the leaders of those countries, military and civilian, were completely sane and sober and in control, what guarantee do you have that that will be the case for all times? It is stupid in the deepest sense to have these weapons. And now as the weapons proliferate to more countries, the chance of a mad leader gaining control over such weapons becomes greater. We have had mad leaders in this century—Hitler and Stalin are two examples; one could think of some more, but those suffice. There is a reason why nuclear weapons are attractive: It's because many nations feel they can't be pushed around as much if they have nuclear weapons.

If nuclear weapons are a sign of being taken seriously, then this is very dangerous. Therefore, it seems to me, countries deserve to be taken seriously whether they have nuclear weapons or not. The responsibility now falls on the shoulders primarily of the United States and Western Europe and Japan to respect these nations and consider their interests regardless whether they possess nuclear weapons.

NARLIKAR: We started with astronomy. I would like to end with astronomy. In India astronomy and astrophysics are receiving special emphasis. We are establishing a lot of facilities all over the country. I mentioned the radio telescope, and other centers also have come up. So, we would very much like you to come to India again and visit our astronomy centers.

SAGAN: Thank you, Dr. Narlikar. I very much appreciate that. From everything I have heard, you're doing a wonderful job, not just in developing astronomical research, but in popularizing astronomy in India.

NARLIKAR: I think your visit has been a boost to us.

SAGAN: Thank you. I congratulate you. □