Estrelas, Ciência e a Bomba: Uma Entrevista com Hans Bethe

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Hans Bethe fala de trechos de sua vida como físico, sobre a fabricação da bomba atômica, desarmamento e a situação atual da ciência.

Abstract

Hans Bethe talks about pieces of his life as a physicist, about the making of the atomic bomb, disarmament and the current status of science.

Hans Bethe faz parte de um grupo restrito de físicos que ficaram para a História. O curioso, no caso de Bethe, é que, apesar de seus 90 anos, completados em julho de 1996, ele ainda faz História. Atualmente, ele é um dos líderes em estudos sobre o mecanismo de explosão em supernovas, tendo começado a trabalhar nesta área cerca de vinte anos atrás, numa idade em que a maioria dos físicos se aposenta.

Pode-se dizer que Bethe tornou-se uma figura lendária da física, sendo o protagonista de uma série de histórias passadas de geração em geração de estudantes. Na presente entrevista, Bethe conta o que há de verdade em alguns destes mitos. Ele dá também sua opinião sobre como deve ser feito o desarmamento nuclear, conta como foi a fabricação da bomba e comenta o que deve ser feito em a ciência hoje em dia.

Minha idéia original era entrevistar Hans Bethe e mandar o trabalho para algum jornal de grande circulação para que o público leigo pudesse conhecer melhor uma importante figura da física. De fato, trechos desta entrevista foram publicados no jornal *A Folha de São Paulo* em 28/07/96. No entanto, como foram deixados de lado os trechos de maior interesse para físicos e historiadores da física, acredito ser oportuno publicar a entrevista completa num veículo mais voltado para físicos, como no presente artigo, especialmente por ter sido convidado pelo editor. Além disso, a entrevista publicada na Folha foi traduzida, o que a faz menos precisa, e leve, em alguns casos, a ordem das perguntas invertida por questões editoriais.

Antes de continuar, vale descrever um pouco como foi a entrevista. Eu cheguei na sala de Hans Bethe na Universidade de Cornell em Ithaca (EUA) numa terça-feira a tarde (21/05/96) e fiquei surpreso em vê-lo firme e forte em seu trabalho: Bethe estava consultando uma tabela com a abundância dos elementos no Universo para comparar com alguns de seus resultados. Apesar de morar nos Estados Unidos desde 1935, ainda mantém um forte sotaque alemão. Ele fala devagar, dando a impressão de escolher cuidadosamente cada palavra. Bethe me pareceu uma pessoa extremamente modesta e simpática e a entrevista transcorreu como num bom "bate-papo".

No que segue, apresento uma pequena biografia de Hans Bethe e depois a versão completa da entrevista com este renomado cientista.

Breve Biografia

Hans Bethe nasceu na Alemanha em 2 de julho de 1906. Obteve seu diploma universitário pela Universidade de Frankfurt e seu doutoramento pela Universidade de Munique, aos 22 anos de idade. O tema era difração de elétrons em sólidos, sob a orientação de ninguém menos que Sommerfeld. Em 1932, já um reconhecido líder da física, obteve uma posição na Universidade de Tübingen. No ano seguinte, com a ascensão do nazismo, Bethe perdeu seu cargo devido à sua origem judaica.

Com a ajuda de Sommerfeld, Bethe obteve uma posição na Universidade de Manchester na Inglaterra. Em 1934, recebeu uma oferta de emprego na Universidade de Cornell (EUA), que até então não fazia parte do circuito da física mundial. Em fevereiro de 1935, Bethe chega a Cornell onde permanece até hoje.

Bethe trabalhou em diversas áreas da física, muitas vezes com contribuições fundamentais. Ele ajudou a formar as bases da física nuclear teórica (principalmente através de seu artigo na *Reviews of Modern Physics* nos anos 30), trabalhou em física do estado sólido, foi pioneiro na criação da Eletrodinâmica Quântica (Bethe explicou o deslocamento Lamb), fez pesquisas em física aplicada (por exemplo, estudou materiais que pudessem ser utilizados em veículos espaciais), explicou o mecanismo de produção de energia em estrelas (que lhe rendeu o prêmio Nobel de 1967), entre outros feitos. Atualmente, Bethe trabalha com explosões de supernovas e astrofísica de neutrinos.

Durante a Segunda Grande Guerra, Bethe trabalhou no desenvolvimento do radar e mais tarde na bricação da bomba atômica em Los Alamos. Como chefe da divião de física teórica do Projeto Manhattan, Bethe foi um dos pioneiros na utilização de computadores, apesar de ele próprio utilizar poucas vezes este equipamento. Após a criação da bomba, Bethe tornouse um dos líderes da luta pelo desarmamento. Bethe teve ativa participação em áreas sociais, combinando sua impressionante carreira em ciência com importantes participações na vida política, tendo participado de diversos comitês norte-americanos e internacionais.

A Entrevista

You are now close to your 90$^{\text{th}}$ birthday and you are still doing research, you are still one of the most important investigators in your field. What is your secret?

Bethe:*Not to do anything for my health.*

Prof. Bahcall from Princeton University once said that you did so many things in physics that if he did not know you, he would be tempted to think that you were in fact many persons conspiring to sign papers with a single name. If this were true, which one would be your preferred Hans Bethe?

Bethe:*First of all, I am a physicist. But, probably, my most productive years were when I was a nuclear physicist, especially when I wrote a long comprehensive paper in Reviews of Modern Physics in 1935 and 1936. Then, I continued in nuclear physics and, in particular, I got interested in nuclear matter in the 1950's. I tried to prove that the forces between two nucleons are just right to explain the binding energy and the density of heavier nuclei. Well, I failed. But, at least, I came somewhat close to it. This is the theory of nuclear matter which was started by Keith Brueckner. I think I simplified it greatly and then extended it to include the correlation between three nucleons.*

People like to tell stories of heroes and some of them are very fantasized versions of what really happened. In the history of physics there are many such stories that involve you as a main character. Let's talk about a few of them to see how they really were. For instance, it is told that you have solved the problem of how nuclear disintegrations took place in a trip by train and then in a subway. How was that?

Bethe: *I got interested in nuclei in 1933, which was essentially following the discovery of the neutron by Chadwick, and I was working together with Rudolph Peierls. We worked very well together at Manchester. We once went to visit the Cavendish Laboratory in Cambridge where Chadwick and Goldhaber have discovered the disintegration of the deuteron by gamma rays. Chadwick challenged us and said: "I bet you can not make a theory of this process". So, on the train back from Cambridge to Manchester, which took a long, long time, we produced the theory, which was mainly based on the idea* *that the forces between nucleons are short range. Using that theory we then also calculated the scattering of neutrons by protons. That was a beautiful theory, very simple. The only problem with it was that it was wrong. It gave a cross-section of 3 or 4 barns and, two years later, it was shown that it is really about 20 barns. Now, this was solved by Wigner in the subway between Columbia University and Penn Station. Wigner suggested that the deuteron also had a singlet state but nobody knew where that might be located. One could deduce that this singlet state had a very small binding energy. I then put that into my Reviews of Modern Physics article and later it was extended by Teller and Schwinger and a very beautiful theory came out of it. So, this could be investigated experimentally by using para-hydrogen to scatter neutrons.*

Then you made another important discovery on a train which basically triggered the development of QED. Do you think trains are a good place for inspiration?

Bethe: *(laughter) No, I don't think so. In both cases, and specially for QED, I was very stimulated and wanted badly to get that theory worked out. I was at the Shelter Island conference and I had the idea that I probably could solve the problem of the Lamb shift. So, the first occasion that I had to sit by myself and work on this was on the train.*

Was it easy?

Bethe: *Yes, it was fairly easy.*

Let me now ask you a question related to your work on energy production in stars that led to your Nobel Prize in 1967. There were strong evidences that lead to the idea that stars were fueled by nuclear reactions. But, nobody knew which were those reactions. You were the first to point them out and verify that they produced the correct amount of energy. Now, students in physics have many stories they tell themselves about famous physicists. There is one in which your girlfriend tells you how beautiful the sunshine is and you respond that it is indeed beautiful, specially because you are the only person who know why it shines. Is that true? In any case, how did it feel to be then the only person to knew why stars shine?

Bethe: *The story you are referring to is not mine. There is a great confusion with respect to it. It was Houtermans who told his girlfriend that. I did not. But, well, how did it go? The idea of the proton-proton reaction was, I think, originally due to Weiszacker but he didn't know how to do it. But Critchfield, who was a graduate student at Ceorge Washington University took it up and said he was going to do it. Indeed, he did it and Gamow, who was his thesis advisor told him: "Well, there is this Hans Bethe who knows a lot about Nuclear Physics. Why don't you send it to him and see if he can confirm it and maybe make it more accurate". So, that's how I got into the proton-proton reaction. Then, a little later, in the spring of 1938, Gamow and Teller organized a conference in Washington after three other conferences which had all been on theoretical physics, but they decided that this time it should be on astrophysics and in particular in energy production in stars. So, that conference was held and was very interesting and in particular one of the lecturers was Strömgren, a Swedish-Danish astrophysicist who told us that the temperature in the center of the Sun was about 20 million degrees rather than 40 million degrees, which was much too much for proton-proton reactions. So, Critchfield and I felt happy because with 20 million degrees we could do very well. By now, it is actually believed to be 15 million degrees, which is still OK. Then, Gamow gave a talk, partly reporting on the work by Weizsacker and both of them were not very interested in the energy production, but on building up elements. There is a great difficulty here. You can get to helium very easily but then there is a gap. You can't add a proton because lithium-5 is not stable and you can't add an alpha particle because beryllium-8 is unstable. So, they had the most weird ideas about how to build up the elements. I decided after that conference that one should separate the problem of energy production from the problem of building up elements. I went to work on energy production and there was the problem that while Critchfield's* *idea worked very well for the Sun, it wouldn't work for Sirius or any heavier star because they had much greater energy production per unit mass and not much higher center temperature. I then searched through the periodic table, just stupidly going one by one. So, without any inspiration, I got to carbon and, in this case, you get a cycle leading back to carbon. That was done about the same time by Weizsacker, but he didn't do anything except to write down these reactions, whereas I wrote a paper in which I calculated the rate of these reactions at various temperatures and found out that these reactions gave about the correct rate and center temperature.*

You mentioned Gamow and there is another story in which Alpher and Gamow invited you to sign a paper that turned out to be very important for the establishment of the Big Bang theory. The reason they invited you, however, was just because the author's list would form the first three letters of the Greek alphabet. How was that?

Bethe:*Alpher, Bethe and Gamow. That was really just a joke. The paper was not obviously wrong so I said "OK, put me on". Now we know the paper is obviously wrong. Elements are not build up in the Big Bang, but in big stars.*

You not only contributed in a decisive way for various fields in physics, but also, in some cases, you were a pioneer, helping to create the field itself. During the process of developing new ideas and even discover new fields of research, do you have doubts?

Bethe: *Well, I have no doubts. Gettings a new theory is a wonderful experience and you are completely involved in it, nothing else matters, it is just a wonderful state of mind.*

Let us now talk about Los Alamos and your work with the atomic bomb. Does it feel contradictory to you that you were one of the main figures on the creation of the bomb and then you were also one of the main figures on the fight against nuclear arms race?

Bethe: *It is indeed contradictory. The Second World War was a very serious matter and the Nazi doctrine upset all western civilization. So, it was obvious that one had to resist it and work as much as possible for the Allies to win the war. So, at a very early time I volunteered to work on the Radiation Laboratory at MIT on radar. I was happily doing that when Oppenheimer asked me to join the atomic bomb project. So, I was among the founders of Los Alamos. When Los Alamos got together in April of 1943, Oppenheimer called in two more experienced people, namely Rabi and Robert Bacher. They had experience at the Radiation Lab and said: "Oppie, you should make divisions of your lab, you can't just run it single handed and, being the director, you can't run the theoretical division". They said the obvious person to run it was Hans Bethe. That was very simple. So, I had a division which was important but relatively small. The lab as a whole, I guess, had three or four thousand employees, most of them scientists or engineers. The theory division had only one hundred, but we got into all areas of the work. In particular, I knew nuclear physics but I had two group leaders in my division who knew just as much, namely Victor Weisskopf and Robert Serber. Most of the nuclear physics was done on those two groups. I got most concerned about the problem of implosion by which the bomb was assembled, so I worked mainly on that. Most of it was done by other people, but I did what I could.*

How was the atmosphere in this place where the best physicists of that time where confined?

Bethe: *They were all tremendously engaged in this problem, we all wanted it to succeed. We all worked together and one thing that "Oppie" instituted was a weekly meeting with the senior people, about fifty of them, which was called the Coordinating Council. There were no secrets, everything could be discussed there. There was no division of knowledge, contrary to the wishes of General Groves and that was essential because we told each other what we have learned and what troubles we had. Often somebody from a different group would have a good suggestion to solve it.*

In the meantime, did you talk about physics in general with your colleagues?

Bethe: *Never. Some people did. Feynman, for instance. But, I felt that this was a big job and we had to do it as fast as possible. There was no time left for anything else.*

Did you also take it as a personal task since you were obliged to escape Germany because of the Nazis?

Bethe:*No, I was part of a team. I did think at the time that the bomb was probably going to be used against Germany, but victory over Germany was achieved before the bomb was ready.*

What did you think when the bomb was dropped?

Bethe: *I think it was right to do so. The main think it saved was Japanese lives. If it hadn't been for the bomb, the fire bombing of the Japanese cities would have continued and the number of casualties would have been much, much greater than it was in Hiroshima and Nagasaki.*

Did the scientists know beforehand that the bomb was going to be dropped?

Bethe: *We assumed it. We were asked to send two bombs to the mid-pacific, so we did. We had a third in readiness. After the Japanese surrender, we got orders not to ship it out.*

How did you feel after the first test?

Bethe: *The first feeling was one of accomplishment. We did it. And the second feeling was horrible.*

In what sense?

Bethe: *This destructive power would now exist and would make wars much worse than it had been. I think it is important to realize that in Japan we dropped two bombs, but at a time the United Sates and the Soviet Union each had ten thousand of them.*

Do you think the ultimate goal of the fight against nuclear weapons should be to wipe them all out?

Bethe: *I don't think that's possible, because making a nuclear weapon is so easy and there are lots of countries which are without consciousness and ought to make troubles. Iraq is an obvious one and North Korea is another. Iraq put lots of effort into making nuclear bombs, but didn't get there. But then, there are somewhat more responsible countries, India for instance. India knows how to make an atomic bomb and I think could do so if they want it. There will be now a new government and you can't tell what they will do. So, there are too many countries around the world which are irresponsible and could make nuclear weapons. And there is nothing to prevent them, except the existence of more stable countries, like the Unites Sates and, I hope, present day Russia which have a certain number of stored nuclear weapons which could be used in an emergency to defeat such a wrong country. I believe something like a hundred nuclear weapons have to be retained by the responsible countries.*

Brazil has not signed the Treaty for Non-Proliferation of Nuclear Weapons because it claims that the treaty not only keeps developing countries from obtaining technology for building nuclear weapons, but more important, because it even keeps these countries from obtaining any kind of nuclear technology, including the ones for peaceful purposes. Do you think that is true?

Bethe: *No, the use of nuclear power reactors is perfectly permissible. In fact, the treaty went together with Eisenhower's call for atoms for peace. And I think part of the treaty says that countries shoukl generally be supported when they try to build nuclear reactors for power. But, in your case, Brazil and Argentina for years were preparing nuclear weapons against each other, but then more reasonable governments came into play and they signed an agreement.*

After the end of the Second World War, mainly because of the success of the atomic bombs, science and physics in particular got huge funding. Now, after the end of the Cold War, the situation has changed again and there is not a

lot of money anymore for science. How do you think science should be done nowadays?

Bethe: *We do the best we can. If we have less money, well, we can't do as much, but we will still do whatever we can.*

Do you think certain felds of science should stop being funded now?

Bethe: *No, I think all science should be funded. Of course, we should not fund crazy science, like cold nuclear fusion. But, whenever there is respectable scientific basis, it should be funded.*

Is there anything in particular that you see as the most important thing in science nowadays?

Bethe: *Let's put it this way: if I were a graduate student now, I would probably study molecular biology. I think that's where the most intportant discoveries will be made in the next twenty years.*

That brings the question: what are you doing nowadays?

Bethe: *In the last twenty years, I have worked with supernova explosions and I think I have a good understanding of the mechanism of the explosion.*

How about your recent work with neutrinos?

Bethe: *I have worked mainly with solar neutrinos. Bahcall and I are of the same opinion that the peculiar observations of solar neutrinos are explained by the MSW theory which says that electron neutrinos are converted into mu neutrinos that you can not observe with radioactive detectors. The crucial experiment is in preparation. It is called SNO [Sudbury Neutrino Observatory]. Last Friday, we had a talk from one of the experimenters and he said it will take about a year before SNO gets into operation. We're very curious about what they will say.*

How is your day nowadays?

Bethe: *I usually come to my office. Today, for instance, I came just at noon, yesterday I came at 10:00, but then I left early. I just do what is necessary.*

I noticed there is a sign close to your blackboard that says: "SAVE". Is there any special meaning for it?

Bethe: *Of course, it is very special. If that sign is on, it means that whatever I have written on the black-board should be saved. The other side says: "ERASE".*