# OPPOSITION TO NEW IDEAS IN SCIENCE

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MR. PRESIDENT and other members of the Breakthrough Science Society, ladies and gentlemen —

First of all let me convey my best wishes to your society and its activities which are very much needed in the present ambience, and I hope that the enthusiasm with which you are pursuing your goals, will be rewarded with success in the course of your life time. It is important to keep pursuing because there is a tremendous inertia in the society to change its point of view, to accept new facts. The human mind, the collective human mind, adheres to what has been accepted till then, even though facts to the contrary are presented.

I am thankful to you for presenting me the picture of Galileo Galilei. In fact I was planning to start my talk with a statement from Galileo. By coincidence you have presented me with Galileo's picture. I do not remember the exact words, but what he had said was that in matters of science, the opinion of a thousand individuals is not more important than the fact-based work of a single individual. That is, if an idea is based on facts and if a single individual proposes that and there are a thousand people against it, it shouldn't matter; because ultimately the facts should prevail. Now, as Galileo found in his lifetime, although he was proposing ideas which were based on facts, he was generally considered an outcast in terms of the then social perceptions and whatever he was saying was banned from publication. His book was put out of circulation and many other restrictions were placed on him. But, as is the nature of science, ultimately facts won through and the wrong ideas or paradigms, which were prevalent, gave way.

This has always proved to be the case because basically science, as a subject, is pragmatic. But the practitioners of science may not be pragmatic, they tend to be more human in terms of their attitude. What we have to remember is that scientists are human beings and whatever failings you associate with the human mind, they may also share. Although they are supposed to be totally objective, they are very often not so. And I am speaking as a scientist, it is my own personal experience that sometimes I myself discover when I do a critical self examination that I had not been objective in assessing certain facts. But then if not 100% at least we should work towards 90% objectivity, and that is what I will call progress. One cannot be perfect in this world, and one has to live with reality. But one should aim for perfection. It is against this background that I want to share with you some ideas on how the theories on the origin of the universe and its evolution, have developed over the present century.

Now I want to stress the words *present century* deliberately because one mistaken idea, which was completely hyped by the media, was that the millennium started on 1st January 2000. This is not the case. Just because your computers failed under the Y2K doesn't mean that your whole value judgement should change. And just as you start counting the days in the month with 1 — you don't have a 'Zero' date, the initial day of the month is 'one' — similarly the years are counted with 'one' and that makes January 1, 2001, the beginning of the next millennium. So we are still in the 20th century, we have not gone into the 21st century. So when I say how cosmology has evolved in this century I mean, how it has evolved between the years 1901 to 2000.

Recently Fred Hoyle, Geoffrey Burbidge and I have written a book called "A Different Approach to Cosmology" published by Cambridge University Press, in which we have outlined the Quasi Steady State Cosmology as an alternative to the standard paradigm, which is, the Big Bang Cosmology. In this particular book we have begun in a historical fashion to show how the development of astronomy of our Galaxy and beyond our Galaxy grew in the beginning of the century; how there were different paradigms, and how some of them gradually fell apart. For example, one of the ideas which was very strongly adhered to by the majority of astronomers was that all the nebulae that you see with your telescope are part of our Milky Way system, our Galaxy. Nebulae are cloud-like objects and it is true that some nebulae do belong to our Galaxy. But there was a small minority, which suggested that quite a few of the nebulae, are galaxies in their own right lying well beyond the Milky Way. So in the beginning of our book we reproduced a paragraph from a popular book in Astronomy by Agnes Clerke, stating that it is now conclusively proved that all nebulae are part of our Milky Way system and there is no evidence whatsoever for believing otherwise. This was written in 1905. And that indicates the general belief held in those days. However by 1925, that is within two decades, the situation changed. With the new telescope of 100 inch (2.5 meter) diameter at Mount Wilson it was possible — and Edwin Hubble played a major role in this exercise — to show that several of these nebulae are not part of our Galaxy but are galaxies in their own right. For example, Andromeda Nebula is actually a galaxy and it is in fact slightly bigger than our own Milky Way system. So these ideas took, as you see, a somersault. What was earlier believed, in 1905, was no longer believed in 1925, because of new inputs from telescopes.

Now by 1929 there was also an accumulation of evidence that the spectra of galaxies showed a shift of absorption lines. With very few exceptions most spectra showed shift to the red end, which gave a naive Doppler interpretation, that these galaxies are moving away from us. So the picture was becoming clear, that our universe made of galaxies is not what you call a stationary universe, not a static universe, but it is expanding. And the final nail in the coffin of the static universe was hit by Hubble when he found that there is a unique relationship between the shift of spectral lines and the distance of the galaxy. In terms of the Doppler interpretation, the farther the galaxy the faster it is moving from us. So this was the interpretation given by Hubble and it became established as Hubble's law.

Now, I can give here an example of lack of objectivity. That is in 1917, Albert Einstein had obtained the model of static universe, because in 1917 there was no reason to believe that the universe was expanding. And in order to obtain a static universe he was forced to modify his field equations by adding an extra term which is called the cosmological term or the "lambda term." So Einstein introduced this term and he very firmly believed as most of the astronomers around 1917-1927 did, that the universe is static. However, around 1922 Russian astronomer Aleksandr Friedmann had worked out models of the universe which were expanding models. And he sent these models to Einstein for his comments. Mathematically they were correct models, but Einstein did not encourage them in any way because he felt that because the universe is static these were mathematical curiosities and as such did not make much physical sense.

However, this prejudice of Einstein's fell apart in the wake of Hubble's law, when it was demonstrated that galaxies are moving away from us and Friedmann's models were actually describing a situation like this. Einstein felt that his original static model was wrong and he switched over to the expanding model. And with de Sitter, who was another leading scientist of his time, Einstein wrote a paper in 1932 which advocated an expanding model. This in known as the Einstein–de Sitter model, although it was already known and worked out by Friedmann in 1922, about ten years earlier. However Einstein also came to the conclusion that the lambda term, the cosmological constant he had introduced, was no longer necessary, to keep the universe static. Thus it was not necessary to modify his field equations. So he said it was a mistake on his part to have introduced the lambda term and he wished to have nothing more to do with it.

But other cosmologists like Eddington and Lemaitre persisted because they felt that with an additional parameter, lambda, you get a wider variety, wider rage, of cosmological models. Now this cosmological term has played a mixed role in cosmology. Just as Einstein threw it away, many cosmologists did so, because it unnecessarily complicates the models. However, whenever new observations showed that their models without the lambda term don't fit, they brought the term back, saying that of course it has to be there. And many times it has happened in cosmological observations that the errors which were present in the earlier observations come to the surface, get recognized, later. And the earlier observations don't mean much. Whenever this happened, cosmologists discovered that the reason for which the lambda term was introduced was after all no longer relevant. So they quietly forgot about the lambda term and worked without it. Again the new wave of observations came and they found that lambda term is needed, so again it was brought in with full fanfare. So there is this wave of up and down in the fortunes of the cosmological constant. Currently it is enjoying popularity. But don't be surprised if after 5 years they again consign it to mothballs. This is how cosmology has worked over the century, so far as the lambda term is concerned.

Let me now come to the model which Einstein, de Sitter, Friedmann, Lemaitre and Eddington proposed. They have all one thing in common, that the universe started with a scale factor which was zero, a finite time ago, And it was interpreted as saying that the universe started with a "Big Bang" because the rate of expansion was very high, actually infinite, when $S$ the scale factor was zero and people said that this was the origin of the universe. The universe expanded with a primordial explosion and it is expanding ever since. So when asked what was the significance of this primordial epoch, what was the physics at that time, the supporters of the model confess that this is beyond physics, beyond astronomy, it is a primeval event which indicates creation of matter. Now, I could not accept that just because today we cannot understand something that is beyond physics. But this has been one of the mysticisms of Big Bang cosmology, that something fundamental, superphysical thing that happened at this epoch. Now at some stage this gets mixed up with philosophical and religious ideas. And when I said that scientists are not always objective, they are common human beings, what we have to remember is that if you are brought up in a society where the philosophical and cultural heritage has been that there was a creation of the universe — and all different religions have had this kind of ideas — then you begin to feel that at last science has reached a level where it substantiates our religious beliefs. But it should be the other way round: Science is not to be used to substantiate my belief or somebody else's belief; that is not what science is all about. Science aims at discovering facts regardless of beliefs and we have to adjust our beliefs to the facts. But sometimes scientists view the facts within the framework of their beliefs.

In our book, which I have mentioned, we gave a quotation by the team leader from NASA who announced the discovery of small fluctuations in the microwave background radiation by the COBE satellite in 1992. He was so overwhelmed in describing this discovery that he said it was like seeing the face of god. Now this statement reflects his inner prejudices. In actuality it was some patchiness in the radiation background. And to liken it to the face of god is to elevate it to a metaphysical level, which the facts don't warrant. But the fact that a scientist like him came out with this spontaneous reaction means that he had been subconsciously guided by some such thinking. So this kind of effect exists even in our modern society where scientists are supposed to be guided by facts. However I will return to this later.

Now, coming to the 1930s, this led to the concept of Big Bang models. Incidentally, the name Big Bang was not given by the Big Bang cosmologists, but was given by one of the leading opponents of Big Bang theory, Fred Hoyle. When giving a course of popular lectures on cosmology he so referred to this model and that name stuck. So everybody started calling that the Big Bang model. And a few years ago one of the magazines, *Sky and Telescope*, ran a public poll in which readers were asked to suggest an alternative name to Big Bang and some names came up. But the jury felt that Big Bang was still the best name. So the name given by Fred Hoyle has struck, even though he had given it in a somewhat derogatory fashion.

Now why did he do that? Let me come to his criticism and the alternative he proposed in 1948, which was the Steady State theory. The objections which Herman Bondi, Tommy Gold and Fred Hoyle, the three cosmologists had against the Big Bang were the following: First of all the age of the universe as calculated in those days turned out to be very much lower — it was estimated at about 2 billion years — even lower than the age of the Earth. So they felt that the universe cannot be as young as this. Instead they proposed a universe without a beginning and without an end. They came up with the steady state model.

Bondi and Gold had a different approach compared to Hoyle. They felt that cosmology should be guided by an overriding principle, which they called *perfect cosmological principle*. Now all cosmologists use a cosmological principle that says at any given time, the universe is homogenous and isotropic i.e., there is no preferred point, no preferred position, in the universe. Bondi and Gold said that after relativity, we are talking about space and time together; so why keep them apart? So the universe should not show any difference from one time to another, it is steady. Steady means, there is no change with time. But it could still expand. But expand at the same rate at all time. So the value of Hubble's constant would be the same. And Bondi and Gold also made a very original point. Supposing you are comparing a distant galaxy with a nearby one in order to test a cosmological theory. You must be sure that the physics which operates here operated on that distant galaxy; it is the same as the physics you know today. Now what is the guarantee for this if the universe is changing? If the universe is evolving as the Big Bang universe does, then you don't have that guarantee that your physical laws don't change. And therefore the only way of doing observational cosmology, that is comparing distant universe with the nearby universe, is to assume that the universe has not changed; then the laws of physics will also not change. And that is the justification they gave for the perfect cosmological principle.

Fred Hoyle gave a different argument. His argument was that singularity which I referred to as the Big Bang instant where physics is denied access, is not the right way to proceed in a physical theory; we should replace it by another, where new matter appears in the universe in a non singular fashion, i.e., where there is no infinity of density, infinity of temperature or where the volume doesn't shrink to zero. It should be a perfectly legitimate physical process and it should also respect the law of conservation of matter and energy. So he invented a mechanism which involved a "negative energy reservoir" called the *creation field*, and he put that as additional term in Einstein's equations and then he could get the Steady State model as the solution. So it was a perfectly legitimate argument, consistent with physics.

But in those days, in 1950s, the Steady State theory was very violently attacked. You should read our book to see in what an unscientific way it was attacked. I won't go in to the details here. But Bondi, Gold and Hoyle stuck to it saying that this is how we would like to present our theory and the best way of testing it is through actual observations. Now, Martin Ryle, who was one of the leading radio-astronomers in Cambridge, felt that he would like to disprove the Steady State theory by counting radio sources. So he went to great lengths in doing this experiment of counting radio sources to different distances. And if the universe is steady the number density of sources further out should be the same as number density here and now, because when you go further out you are looking at the universe back in time. And if the universe was equally dense then as it is now, then the universe must be steady. On the other hand if it was denser in the past then it is unsteady. So he felt that he could disprove the Steady State theory by showing that the source density in the past was more than it is now. He came up with the first observation to disprove the Steady State theory in 1955. There was a certain slope of the number count curve, which he claimed as a disproof and it was close to 3, whereas the expected slope was 1.5. So he said this was a clear indication that the steady state prediction is ruled out. However two years later he revised his observations because there were lots of errors in it. And he came out with a conclusion that the slope was 2. So he said it is still more than 1.5, so it is a disproof of steady state theory. Now by then the Australians had their own radio telescope, and they were also conducting the survey of radio sources and they came with the report that the slope was close to 1.5, it was not as high as Ryle was claiming. And so there was a conflict between Ryle and the Australians. But Ryle refused to accept the Australian criticism. Then in 1960-61 Ryle came up with one more observation in which he revised the slope down to 1.8. Thus it came from 3 through 2 to 1.8. And again at that stage he claimed that the steady state is wrong and a great deal of newspaper publicity was given to this result. The newspapers put in religious connotations that Ryle supported the idea of divine creation.

At that time I was a research student of Hoyle, just newly recruited. In February 1961 Ryle was going to present his data to the Royal Astronomical Society, and Hoyle felt that we should reply to his criticism. So we constructed a counter example, which showed that the Steady State theory was not disproved by Ryle's data; there was enough scope for fluctuations of the result so that it was not statistically significant. However, as it happened, on that day Hoyle was preoccupied elsewhere, so he asked me to present his work to the Royal Astronomical society. I was first scared to take part in a debate with a distinguished and seasoned astronomer like Martin Ryle. But Hoyle told me, if you believe your calculations are correct then there is nothing to worry about it, you could go ahead and present them. And he also trained me in the art of presentation. I found that training extremely valuable, and I was quite confident on that day when I presented the work and it went down very well. Incidentally on that day Bondi was also asked to comment, as he was present. So Bondi got up and said that "in 1955 Ryle said the slope was 3; then in 1957-58 he came down to 2; now he has come down to 1.8; I am willing to wait for a few more years till he comes down to 1.5." This was a very cynical comment which Ryle of course did not like. Any way, to cut this long story short, the last word in this debate was not said in the 1960s, but in the 1980s. By 1985, all the radio sources, which were counted by Ryle, were also seen through optical telescopes and their red shifts were measured. So we know how far they are. This information was not known in the 1960s but by 1985 all the red shifts were known, so we could do a calculation. Patrick DasGupta, Geoffrey Burbidge and I wrote a paper in which we took all the sources and showed that their observations are consistent with a non-evolving model including the Steady State model. So the source count that was much publicized in the 1950s and '60s has ultimately shown that it does not really have the ability to distinguish between cosmological models; it is not the key test that it was thought to be at one time.

And this is another point that I want to drive home: in cosmological observations there has always been a tendency on the part of observers in saying that their observations are perfect and that they clearly disprove a certain theory, and time and again they are proved wrong. Also, by the time they are proved wrong, their initial statements are forgotten and they are able to get away with their new statements. So now, this is more like the debates on topics and issues in politics which rely on short public memory.

Take another example: one of the tests of cosmology was what is called the extension of Hubble's law. When you look at a very remote galaxy you begin to see how the effect of expansion of the universe affects the Hubble relation. Allen Sandage, a student of Hubble, made it his life's work to complete the test. And over a couple of decades he worked on this, to measure the deceleration of the universe. That is, if the universe is expanding, because of its gravitation the expansion should slow down. This is what the simplest Big Bang model suggests. So the deceleration was to be measured. And Sandage kept getting values, which showed that the universe is indeed decelerating. Steady State was the only model which stated the universe should accelerate. And so during the 60s and 70s the steady state theory was again shown in text books as a theory which doesn't agree with observations. Well, as I mentioned to you, observations have taken an about turn in 1998-99. The studies of supernovae give revised distance estimates of galaxies and these begin to suggest an accelerating universe. To explain acceleration the cosmological constant was brought in. And there was no mention in any of the papers that the Steady State model had earlier predicted accelerating universe. So you can see how short the memories of these scientists are.

The main problem, which the steady state cosmology faced, however, was in explaining the microwave background radiation. This radiation background was discovered accidentally in 1965. And it is considered the major achievement of Big Bang cosmology. In the 1948 when George Gamow was discussing the early hot universe his coworkers Alpher and Herman published a paper in Nature in which they said that if the universe was very hot soon after the Big Bang, it must have cooled down now and they said its temperature might be around $5^o$ (Kelvin) today. This temperature was not actually calculated (in fact in Big Bang cosmology there is no way of calculating the present temperature) but guesstimated. The fact that it was a guess can be seen in the following way; Gamow had been asked subsequently and he gave a temperature of $7^o$ on one appraisal and then he gave a temperature of $15^o$, then it went to $20^o$ and even upto $50^o$. Indeed one paper in a scientific journal has given the chronology of Gamow's predictions, which were all guesses, of microwave background temperature. So, when you remember that the radiation energy goes as the 4th power of temperature, you can see how much out you are! You are out by several orders of magnitude in energy if you guess the answer as $50^o$ and it turns out to be $2.7^o$. Still this is considered a major achievement of Big Bang cosmology.

The steady state cosmology was not able to explain this, and therefore it fell down in credibility ratings. However in our book we have mentioned one incident: in 1955 Bondi, Gold and Hoyle had calculated that if all the helium found in the universe were made inside stars, how much energy is released. This is a very simple calculation, and they got a certain figure. Then Gold came up with the idea that if you thermalise that radiation, that is, make it into black body then you will get a temperature of $3^o$. And he said, why don't we publish a paper saying that in steady state cosmology this process works and you get a radiation background of $3^o$? Bondi and Hoyle, however did not support this idea and it remained unpublished. But now they regret having done that because if they had written that paper, the steady state theory would have got the credit for predicting the microwave background radiation with correct temperature.

During the seventies and eighties the Steady State theory remained dormant and in the nineties Burbidge, Hoyle and I felt that we should revive it in a slightly different form, which we call the Quasi Steady State Cosmology (QSSC). We wanted to relate it more strongly to the astrophysical nature of the universe, not to keep cosmology as just a mathematical exercise of Einstein's general relativity. And we noticed that by then there was enough evidence for explosive production of matter and energy in active galactic nuclei and quasars. We felt that these are examples of creation of matter, which the steady state theory used to talk about; but here creation occurs not uniformly and continuously everywhere, but in mini bangs and in small pockets. We felt that this should be the basis of a new cosmology and we put in the paraphernalia of field equations and so on to derive the quasi-steady steady state solution. It describes an oscillating universe which has a long term steady state expansion. In 1993 we published our first paper on this new model.

We have made several predictions on the basis of that cosmology. First of all, it takes account of the fact that creation of matter is going on in many creation events like active galactic nuclei, radio sources and so on; we also find that in this cosmology which is of course endless and without a beginning, stars are born and die in each cycle. So if you take all previous generations of stars what has happened to their light? We found that if we thermalise it we get a 2.7° background which is exactly what is observed as microwave background. So it is possible to relate the temperature of the microwave background to the previous generations of starlight which has been handed down from one cycle to another.

What about the 'face of God' — the heterogenity of microwave background? Now, of course, it has no special, deep, significance like that! The distant clusters and starlight of previous generations contributes to the microwave background. So if you consider the relatively nearby sources, they will produce a patchiness in the distribution. And that patchiness is exactly what is being found, and claimed as of deep significance in the Big Bang scenario.

The physicists among you should appreciate the fact which Fred Hoyle has stressed many times, that if the microwave background is a perfect black body distribution; which is known to arise in a situation of perfect equilibrium, then you cannot locate its individual sources. However, if you find some patches in that equilibrium then you can relate those to individual sources. On the other hand what the Big Bang people tried to do is to look for perfect equilibrium on the one hand but on the other use the patchiness to read deep significance into its origin whereas thermalisation should have wiped out any of those initial conditions. Hoyle has given the analogy that a mountaineer who is lost in the fog sees a perfectly isotropic fog around him. And that is what it is — the microwave background is an isotropic fog developed in the universe. There is no deeper significance in that, it is simply thermalised, completely isotropized radiation. Many Big Bang people appreciate this analogy, but they still do not want to admit that this is the way microwave background should be looked at.

I would like to end my talk here with one comment on sociology which illustrates how today's science progresses. You gave me the picture of Galileo. And you know Galileo had a lot of problems in propagating his ideas. Galileo had those problems because he was against the religious establishment and that religious fundamentalism essentially put a stop to his activity. You might add that such things don't happen today. However, today you have got what I call 'fundamentalism in science' — which comes about in the following way. Suppose you have been promoting a very popular theory. Any research work today requires a lot of money and the money for it usually comes from government coffers. So you have to make a proposal for funding your research.... And if you have established credibility already — you have worked on, say, Big Bang cosmology, then others will say this is a safe kind of proposal; let us fund it. But if you send a proposal saying that we would like to question some of the established doctrines, say, some of the results of Big Bang cosmology, then they would say that this a very contentious proposal, we don't know what will come out of it, so let us not waste money on it; let us not fund it. A proposal which Geoffrey Burbidge sent 3-4 years back to NSF for work on this cosmology, was turned down by one referee saying that this is such a scatter-brained idea, that no research student or post-docs, should be allowed to work on it. Another referee wrote that this is really an unsafe and scatter-brained idea and it is proved by the fact that there are no post-docs and research students working on it. So you see there is a vicious circle! How will you get research students and post-docs working on it unless you have the proposal funded?

I wrote a millennium essay in Nature this year where I gave an example which I had heard from the late Professor Chandrasekhar: He mentioned that when the 200-inch telescope at Mt. Palomar was funded in the late 1930s and it was going to be built, there was a press conference in which both Hubble and Eddington were present. And they were asked: "Sir, if you build this telescope what do you expect to find with it?" They replied that if you know the answer there is no purpose in building it. It was a perfectly legitimate and open-minded answer. But today if you have a proposal for building a telescope you have to give a detailed reasoning; what do you expect to find with that telescope. That means you already have made up your mind what you are going to find. And it is based on what you already believe in. So you are not going to discover anything new except by sheer fluke. This is a very unfortunate direction in which science is going. Because a lot of money is involved, scientists like to play safe. So today there is no such thing like venture funding in science. I made a case that a certain fraction of the money should be available for venture ideas. Howsoever crazy you think it is, if the proposer has established credibility, if he has done good work in the past, and if he is saying that we should explore this, we should support it. And I feel that that is the only way we can rescue science from being bogged down into a completely conformist exercise which is not the way it should be.

Thank you for your patience ! □