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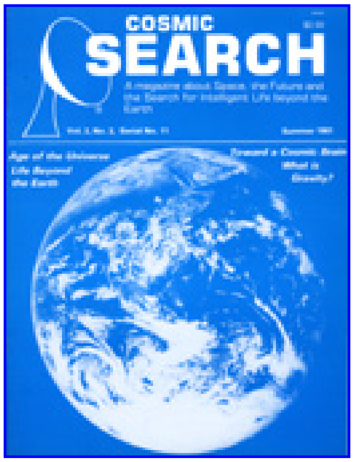

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The Age of the Universe — An Interview with William A. Fowler

By: Robert H. Van Horn

The following interview was done originally for broadcast over Public Radio Station WOSU in May, 1980 by Robert H. Van Horn, Science Reporter for WOSU and Contributing Editor of **Cosmic Search**. It is reproduced here with WOSU's permission. WOSU is operated by the Telecommunications Center of The Ohio State University. Dr. Fowler had delivered the annual Alpheus W. Smith Lecture in Physics at the University on the subject, "The Age of the Universe."

Cosmic Search: Dr. Fowler, how old is the Universe?


William A. Fowler

Fowler: In my view, the Universe is twelve billions years old. Although that duration of time is almost incomprehensible in terms of human experience, we can claim that the uncentainty only falls in the range of ten to fifteen billion years.

C.S.: This is your own estimate. How did you make it?

Fowler: Traditionally, the age has been derived from the redshift measurements which were first perfected by Edwin Hubble and showed that we live in an expanding universe. When Hubble looked at distant galaxies, he found that they were receding with velocities that were proportional to distance. This velocity redshifted their light, and in that way he was able to measure their velocities. Also, by various schemes he was able to estimate their distances. If you know the distances and the velocities, you can estimate how long it has been since the galaxies were much closer together right after the Big Bang back in the beginning of the expanding universe.

C.S.: That seems relatively straight-forward.

Fowler: Those measurements are very sophisticated and very beautiful, but in spite of that, there are considerable uncertainities. Although the age of the Universe as derived from the redshift measurements is consistent with the twelve billion years which I believe to be correct, the uncertainty spreads all the way from seven billion years to twenty.

C.S.: These numbers then are not really measurements of age, but estimates?

Fowler: Well, of course, the redshift gives the velocity quite directly and very precisely if you believe it is a cosmological red shift as most of us do. It is named for the Austrian physicist, Christian Johann Doppler (1803-1853) who found the shift in the wavelength or frequency of sound from sources moving relative to the listener. It is also known as the Doppler Shift. The real trouble is that you can't pace off the distance to a galaxy, and astronomers, following Hubble and his contemporaries, have developed many clever indirect ways of determining the distance to a galaxy. It starts with parallax measurements on nearby stars, but eventually it all boils down to establishing certain types of galaxies as "standard candles." All of these standard galaxies have the same power output. The uncertainty is in the distance scale. That translated directly into the time scale using the redshift determination of the velocities.

C.S.: As I understand it, your measurement of the age of the universe is by a different method.

Fowler: Yes. I'm a nuclear physicist, so early in the game when my colleagues, Fred Hoyle and Geoffrey and Margaret Burbridge and I, came up with the general idea of the synthesis of heavy elements, including the radioactive ones, in stars, we realized we had a way of using nuclear radioactivity in cosmochronology, just as a geologist uses the radioactive elements to determine the age of a rock. In dating the time of formation of a rock, a geologist may have reason to believe that the rock had no lead in it when it was formed, but did have thorium which is radioactive and which decays to an isotope of lead. If he looks now at how much lead is in the rock, he can tell when that rock became a closed system.

C.S.: In other words, the geologist used radioactive decay of the elements as a geological clock.

Fowler: Yes Cosmo-chronology works much the same way, but with additional complications. Over the history of our Galaxy, we think that stars have been producing the heavy elements which some 4.6 billion years ago condensed out of the interstellar medium into the solar system. We are interested in understanding the relative amounts of thorium and uranium and the other radioactive elements so that we can use these nuclear chronometers in a manner similar to using an hour glass. I often refer to these nuclear chronometers as "eon-glasses," since they measure eons rather than hours. By studying the problem for some twenty years now, Barbara Zimmerman, my present colleague, and I have finally refined it to where we believe that the best estimate is twelve billion years, and that it cannot be much less than ten nor more than fifteen. Other methods are consistent with this, but being a nuclear physicist, I believe that the nuclear chronology gives the most accurate determination.

C.S.: Part of your work which led to this, as you just mentioned, was your development of the understanding of the synthesis of the heavier elements in the stars.

Fowler: Yes. As I noted previously, this work was done along with Fred Hoyle and Geoffrey and Margaret Burbridge. Geoffrey is now director of Kitt Peak National Observatory and Margaret is Professor of Astronomy at the University of California at San Diego and president-elect of the American Association for the Advancement of Science. Fred has retired as the Plumian Professor at Cambridge and lives in the Lake District of England. Most cosmologists now believe in the Big Bang as the start of the expanding universe. Nuclear physics tells us that the heaviest element produced in the Big Bang was helium. There was lots of hydrogen, and some helium, but no heavy elements except perhaps a trace of lithium; no carbon, no lead, and in particular no uranium and thorium.

C.S.: I see.

Fowler: We have known for almost the whole of this century that stars probably shine on nuclear energy. When they shine on nuclear energy, they convert one form of nuclear matter into another. The sun in [sic; "in" should be "is"] shining on the conversion of hydrogen into helium. When the sun becomes what astronomers call a red giant star, it will shine for a while on the conversion of helium into carbon. So the very process by which stars give off energy transforms lighter elements into heavier ones. To make a long story short, we worked out processes, — a number of them, and they are not simple — processes which take place during the lifetime of stars which can eventually build all the way up to the heaviest elements like uranium and thorium, and all the ones in between.

C.S.: That's a very impressive structure.

Fowler: I think it's fair to say in general that the astronomical observations and experiments in nuclear laboratories — although they have modified the picture and I think that's great — have led in the main to the acceptance of this point of view of the synthesis of the elements.

C.S.: It strikes me as you describe these processes, and in particular your eon glass concept, you had to have an eon glass full of thorium to start with to get your time scale started. But there was no thorium at the time of the Big Bang. There must have been an interval before you had the thorium to fill your eon glass.

Fowler: Oh yes. We have to take that into account. The contents of the eon glass we're talking about is the interstellar medium, the gas and dust in between the stars on our Galaxy. When a star is formed, it is formed with an abundance of thorium and uranium characteristic of the interstellar medium in the Galaxy at that time. Since we know that the solar system is 4.6 billion years old, we are interested in what was in the interstellar medium 4.6 billions years ago. Since the time when the solar system condensed out of that medium, it has been a closed system. No new elements have been put in, no new thorium and no new uranium.

C.S.: This 4.6 billions years is a lot less than the twelve billion years which you assign as the age of the universe.

Fowler: Yes, and I want to emphasize what that 4.6 billion years means, compared to the twelve billion years which is the age of the universe. I must also emphasize that we think all galaxies were formed very soon after the Big Bang, so our Galaxy is approximately twelve billions years old. We have independent ways of measuring the age of the oldest stars in the Galaxy, and their age is indeed about twelve billion years. So, you see, our Sun, our Solar System, is a late comer. The

Galaxy started twelve billion years ago, and before the Sun formed, there were 7.4 billion years which involved the birth, evolution and death of stars. When a star dies, it sometimes ejects matter into the interstellar medium. The star explodes; the most spectacular examples are what astronomers call supernovas. They eject material back into the interstellar medium, but that material is enriched in nuclear debris. The ashes of the nuclear fires which fueled the star while it was shining produced heavy elements in the star which are ejected into the interstellar medium. When a new star forms as our Sun did 4.6 billion years ago, it inherits, for example, thorium which had been made by earlier stars which were born soon after the formation of the Galaxy and on up to the time when the solar system was formed.

C.S.: Now that we have filled in the geneology of the elements and the solar system, I wonder what you see as the next big steps for astronomy?

Fowler: To that question, you'll get an answer that depends on the person of whom you ask it. I'm still interested in the question of how the heavy elements are produced, and in particular, what can astronomical observations tell us about the sites, the places where nuclear synthesis occurs. We think supernovas in which a star suddenly explodes are such sites. The Crab Nebula is an example. If you look in the direction of Taurus you can see a nebulous region, and if you look with a high powered telescope, you can see tangled filaments of gas moving outward. We know that Oriental astronomers saw a new star in that region of the sky in the year 1054 A.D. which they called a "guest star," which I think is a delightful term. That was the explosion. The star had been too faint for them to see previously, but when it exploded and became a supernova, they could see it. The expanding material became the Crab Nebula. When we look at the Crab Nebula now, we find that there's a pulsar in the center of it. There is a stellar object there that is flashing on and off. We think it is a rotating neutron star. It's like a giant light house. The star produces a rotating beam. If you look one instant you see the beam. Then it is gone. One thirtieth of a second later it has returned. So you see a "pulsing" beam. It's really more like a light house beam and pulsar is a bit of a misnomer. We think what happened in this case was that the central region of the star collapsed. The collapse gave up a great deal of gravitational energy which was transferred in a shock wave to the outer part and blew the outer parts off.

Just now you asked me what has this got to do with the new astronomy. These objects are not only giving off radio emission and optical emission. They are also giving off X-rays and we think they are giving off gamma rays. In fact we know that the Crab Nebula is giving off gamma rays. The only way you can study X-rays and gamma rays is to get above the Earth's atmosphere. I think some of the big steps in astronomy are going to be the studies of these objects that made the stuff that you and I are made of, by looking at them with satellites that have big X-ray telescopes and gamma ray telescopes.

C.S.: What does this mean in the way of opportunities for young astronomers? Do the problems in funding for this sort of work put a limit on these opportunities?

Fowler: Of course, that is a problem. There's no question that federal space program funding has been going down in recent years. That means there are fewer opportunities for young people to come into astronomy. The funding of ground based astronomy has not increased in proportion with inflation. But my one answer to that is, "You don't go into astronomy for the money."

There are many dedicated young astronomers, and they are going to make do somehow.

C.S.: I'm glad to hear you say that.

Fowler: You don't have to emphasize the direct technological spin-offs from astronomy or the space program which I think have changed life for all of us. Astronomy makes a great contribution to human knowledge and culture. We're all interested in the stars. We're all interested now [sic; was "now" intended to be "not"?] only in the history of the human race, but the history of the earth, the history of the Sun, the history of the Galaxy, the history of the Universe, so I can't believe that there isn't going to be support for this marvellous science of astronomy. I'm also perfectly willing to admit and I think everyone in physics and astronomy has to realize that when times are tough, we all have to share some of the lumps with the rest of society. We can't go on doing things as usual. We've got to take some of the cut backs. We must spend some time on socially valuable applications. But we can also expect continued support of the basic sciences, and I think it is pretty clear that there are payoffs there, technologically from the spin-offs, and culturally from the gains in new knowledge about the world around us.

C.S.: Thank you, Dr. Fowler, for these very thoughtful insights.

William A. Fowler

William A. Fowler is Institute Professor of physics at the California Institute of Technology. Born in Pittsburgh in 1911, he received a Bachelor's degree in Engineering-Physics from the Ohio State University in 1933 and a Doctor's degree from the California Institute of Technology (CIT) in 1936. Dr. Fowler has been on the staff of CIT since that time with several leaves as lecturer at Cambridge University, England. He has served as a member of the Science Board of the National Science Foundation, the Space Science Board of the National Academy of Sciences and the Space Program Advisory Council of NASA. Dr. Fowler has received numerous awards and medals including an honorary Doctor of Science degree and the Lamme Medal from the Ohio State University, the Bernard Medal from Columbia University, the Apollo Achievement Award from NASA, and the National Medal of Science.

Dr. Fowler has published numerous articles on nuclear forces, nuclear spectroscopy and nuclear structure. In particular he has pioneered in studies of energy production in stars and how elements are formed in them, collaborating in this work with Margaret and Geoffrey Burbridge and Fred Hoyle. Their hypothesis that all elements might be produced in stars brought additional nuclear processes into recognition leading to explanations of how heavy elements have been built up through enrichment by stars of the interstellar medium and the formation of successive generations of stars.

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