

The History of Cosmology as I Have Lived Through It

Victor S. Alpher, PhD

“Besides his great intellectual achievements, Ralph Alpher was a gentleman of unfailing kindness and a keen sense of justice.” -Samuel L. Marateck[1]

Editor’s comment: The pioneering papers of Alexander Friedmann (1922) and Georges Lemaître (1927) showed how general relativity, applied to cosmology, allowed the notion of an expanding universe. The implications for matter and radiation were given a conceptual foundation with the 1948 PhD dissertation by Ralph Alpher, laying the groundwork for early-universe nucleosynthesis calculations. Alpher’s PhD advisor, George Gamow, a famous prankster, put Hans Bethe’s name also on Alpher’s Physical Review paper, so the publication could be known as the “ $\alpha\beta\gamma$ ” paper. Thus the graduate student Alpher saw his contribution eclipsed by the luminary names of Bethe and Gamow. Later in 1948, Alpher, with his Johns Hopkins Laboratory colleague Robert Herman (who disappointed Gamow by declining to change his name to “Delter”), predicted the existence and temperature of the cosmic background radiation, the afterglow of the big bang. Between 1948 and 1965 they elaborated this prediction and made repeated efforts to convince radio astronomers to search for this relic radiation, but those efforts were frustrated. In 1965, Arno Penzias and Robert Wilson found the background radiation serendipitously. Neither the Penzias-Wilson announcement, nor the companion interpretation of it by Dicke, Peebles, Roll, and Wilkinson, mentioned the Alpher-Herman prediction they had just confirmed. In a 1996 symposium honoring Gamow, Robert Herman recalled:

“The interpretation of the Penzias-Wilson observation by R.H. Dicke, P.J.E. Peebles, P.G. Roll, and D.T. Wilkinson at Princeton unfortunately contained no reference to the eight previous publications containing theoretical calculations of the background radiation. We would also note that Y.B. Zel’dovich, I.D. Novikov, and A.G. Doroshkevich in the USSR did refer to our early calculation, albeit incorrectly attributing it to Gamow, and suggested the use of a satellite to observe it. This was in the year prior to the Penzias-Wilson observation.

“By early 1967, the turn of events led Gamow to become very perturbed by the continuing lack of recognition of our contributions....”[2]

Four Nobel prizes have been given for measurements of the cosmic background radiation. Everyone familiar with the history of cosmology realizes that Alpher and Herman, who predicted its existence and temperature in advance, should have been so recognized too. Whatever the Swedish Academy thinks, they are Nobel Laureates in the minds of the community whose opinion matters. We have the honor of publishing the recollections of Victor Alpher, Ralph Alpher’s son, concerning these events. This article forms the third in his three-part series.[3]

A Personal End and a Beginning

In 1948 my father earned a doctorate at George Washington University for his dissertation on nucleosynthesis. The dissertation argued that the elements were built by neutron capture processes, with beta decays, in the hot environment of the early big-bang universe. This calculation was placed before the physics community in the now-famous “ $\alpha\beta\gamma$ ” paper of 1948, “The Origin of Chemical Elements.”[4] Gamow’s “prank” added Hans Bethe’s name to obtain the $\alpha\beta\gamma$ association.[5] The 2005 National Medal of Science, presented to Ralph A. Alpher in 2007, was conferred “For his unprecedented work in the areas of nucleosynthesis, for the prediction that universe expansion leaves behind background radiation, and for providing the model for the Big Bang theory” (see Figure 1). The paper of 1948 and the 2007 National Medal of Science form the bookends to his life as a cosmologist.

By the time I was 10 years old, I was aware that my dad was a special man and unique scientist. More than once, at interviews for academic positions I was greeted with the question “are you Ralph Alpher’s son?” For example, as a graduate student at Vanderbilt University, my committee chair, Professor Richard Blanton, announced (without my knowledge) my intellectual pedigree to the faculty before whom I would have to defend my graduate work. I have developed great empathy for the offspring of famous people! My father’s reputation influenced my life in many unexpected ways.

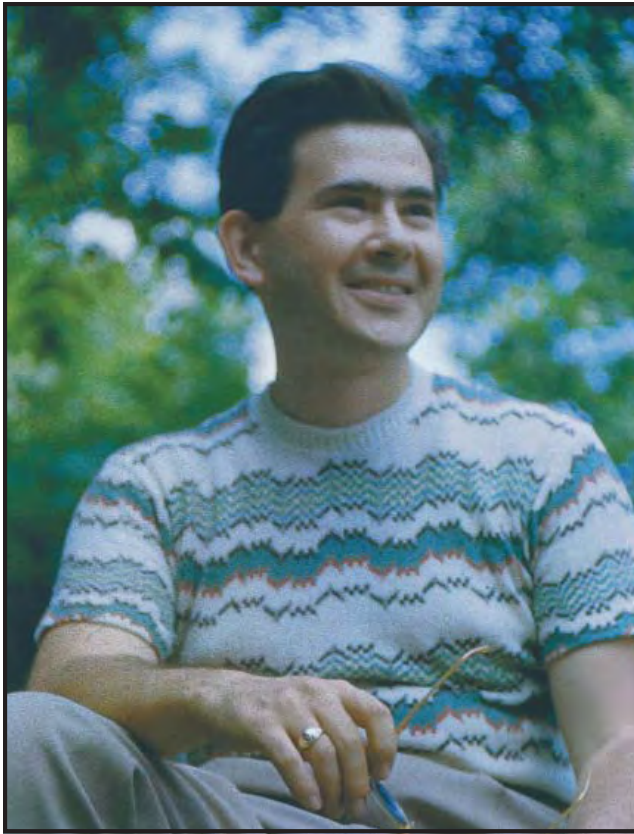
In October 2006, John C. Mather and George Smoot were awarded the third and fourth Nobel Prizes for precision observations of the Cosmic Microwave Background Radiation (CMBR), observations that greatly strengthened support for the big bang model. They headed large teams that designed and managed the Cosmic Background Explorer (COBE) satellite, launched in 1989. My father and Bob Herman were invited to attend the COBE launch, which they did.[6]

Since my dad’s passing in 2007, several of his colleagues have graciously spoken with me about their memories of my dad and their work with him through the decades since the 1940s. Many of these people have been important role models in my life. They showed me how meaningful a life in science can be. This paper also acknowledges them.

My father spoke and wrote often about his experiences, but some events he never disclosed in detail. When he left his papers to me, he knew I would study and interpret them. His “unfinished business” became mine.

Ralph A. Alpher’s Career in Cosmology Begins

Dad wrote *two* dissertations as a graduate student of George Gamow’s at George Washington University. The first one examined density perturbations that would



1. Ralph A. Alpher in 1948, age 27, the year of his dissertation defense.

lead to galaxy formation in an expanding universe. In 1946, when he had just about completed it, Gamow came into dad's office at Johns Hopkins University Applied Physics Laboratory (JHUAPL) where both of them were consultants. Gamow was "waving in his hand" a copy of the *Journal of Physics of the USSR* in which Evgenii Lifshitz reported the same findings that my dad reached in his dissertation. So Ralph had to begin anew on another dissertation topic, for as he told me many years later, he had been "scooped." Nucleosynthesis was at that time in need of serious theoretical underpinning. In 1946, Gamow had suggested that the relative abundances of the elements might be explained by a combination of neutron capture and beta decays.[7] To make the idea precise he needed a superlative mathematician, and my father fit the bill. So began dad's career in cosmology.

In 1948, my dad defended his dissertation on the synthesis of hydrogen and helium. Some 300 people attended his defense! In the ensuing seven years, he would be active on national defense problems with his colleagues at the JHUAPL, but in their "spare" time, Alpher and Gamow, with Robert Herman and James Fol- lin, advanced a cosmological model that came to be called the "Big Bang Theory." In a series of papers they built on Alpher's nucleosynthesis theory to develop its infer- ences for the interactions of matter and radiation in the very early universe.

In 1948, while making a correction to a note about nucleosynthesis that Gamow had just published in *Nature*,[8] Alpher and Herman also predicted the existence of the CMBR and estimated its present tem- perature to be about 5 K.[9] Throughout the 1950s, they

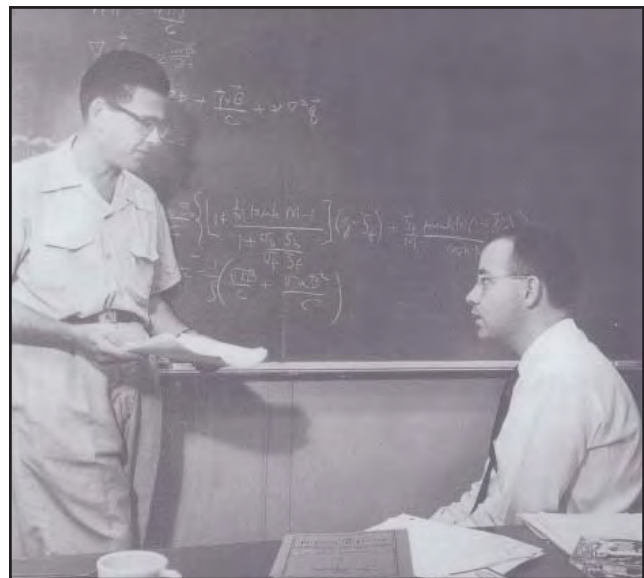
persisted in seeking a radio astronomer to confirm the existence of CMBR and measure its temperature.

These ideas and theories are, still today, at the center of cosmology and are grounded on my father's early work on nucleosynthesis of hydrogen and helium.

Growing Up in my Father's Shadow

I was born in 1954 shortly before my dad left the JHUAPL for the General Electric Research and Develop- ment Center (GECRD). In 1955 we moved from D.C. to Burnt Hills-Ballston Lake, a rural community near Sche- nectady, New York. As a young boy I craved opportuni- ties to go to "the Lab." It was the most wonderful place to imagine working I had ever seen. Later, I learned that my father's world was much larger than Schenectady, and I would find my way into it.

Our family lived in a small, barn-red frame house with a well, from 1955 to 1962, in what had probably been a patroonship dating back to the time New York was a Dutch colony. Our house was about a 45-minute drive on two-way roads north of the GECRD. In the win- tertime, driving to and from work during the 1950s must have been quite a change for my father, who was used to the public transit system and streetcars of Washington, D.C. In the area there were many old red barns going back to the 1700s, with their construction dates intri- cately displayed in their slate roofs—few remain today. Here, just miles from the Saratoga Battlefield, I devel- oped a great love of history. This was encouraged on our regular family vacations, sometimes family camping, throughout my childhood. I walked battlefields of the Revolutionary War and later conflicts, and in 1964 wit- nessed the 100th anniversary re-enactment of General Jubal Early's attack on D.C. in northwest Washington at the Battle of Fort Stevens, where President Johnson sent a wreath commemorating the losses of both North and South. A stand-in for Abraham Lincoln was there, as the 16th president had traveled from the White House to see the defense of the federal Capital. There was certainly no sign of today's political correctness in the event, or in the



2. Photograph in the late 1950s of Ralph Alpher and Charlie Muckenfuss, of the "Re-Entry" group at the General Electric Research and Development Center.

commemorative brochure, which I still have today.

Dad also encouraged interest in science and mechanics. As a student at Theodore Roosevelt High School in Washington, his class disassembled and reassembled an early Ford engine. In the 1960s, he and I together built a see-through V-8 model engine. We spent cold nights looking at the sky through a 6-inch telescope. With some of my Russian grandfather's tools he lent me, I did woodworking projects in our enormous basement. Dad built a darkroom where I learned to develop and print black-and-white photographs. Together we constructed a model binary computer. I learned Morse code and, with him at the other end of the telegraph line, studied for a first class radiotelephone license. I became an Eagle Scout 37 years after he did. My dad played the baritone ukulele, my mother had been a cellist, and I started piano lessons at age four and the violin at age eight. I developed many interests similar to my Dad's—science, music, languages, ethics, statistics, and community service.

Scientific citizenship (a theme of Sigma Pi Sigma and *Radiations*) was part of my father's life. He was elected a councilor of the American Physical Society. He researched the employment picture of physics doctorates at the national level.[10] Particularly after 1965, he became active in his local community, on the boards of the local public television station (WMHT) and the local Unitarian Society, the latter a refuge for the local overabundance of scientists caused by the GECD, Knolls Atomic Power Lab, and other institutions. At times he served as President of both organizations. He was a math tutor, an astronomy and photography merit badge instructor for the Boy Scouts, and, in 1960, was on a YMCA championship volleyball team. As an Eagle Scout he was active in the local Cub Scouts and Boy Scouts. Family, community, and society meant a great deal to him. Although these activities consumed much time, my father nonetheless continued to write and co-author major papers on cosmology throughout his career, through his time JHUAPL, General Electric, and later as a member of the faculty at Union College and administrator of Dudley Observatory.

Looking back on his career, I marvel at the energy and intellect he poured into parenting, as well as into his study of physics. By the time I was eight years old, I knew how important was my dad's lifetime "avocation"—his word for his passion in cosmology. In 1955 when my father and Bob Herman left the Washington D.C. area, they did not leave behind their passion for cosmology. Ten years after our move, the CMBR they predicted in 1948 would be accidentally discovered with a microwave receiver in New Jersey, the discoverers oblivious to Alpher's and Herman's prediction. Meanwhile, as I would later learn, radio astronomers on the other side of the world, in Russia in the 1950s, had paid attention to the ideas of Alpher and Herman.

1965: A Pivotal Year for Cosmology

On 1 July 1965, two articles appeared back-to-back in the *Astrophysical Journal*. The second, by Arno Penzias and Robert Wilson, announced the detection of a "Measurement of Excess Antenna Temperature at 4080 Mc/s." [11] It was preceded by an interpretive paper authored by Robert Dicke, Jim Peebles, P.G. Roll, and D.T. Wilkinson from Princeton. [12] Together these two

papers reported the discovery of the CMBR at a temperature of about 3 K. Cosmology was abruptly buzzing. In the Alpher household we sensed the excitement: My father's prediction about the cosmic background radiation had been confirmed! It was probably inevitable that he would begin to wonder what these observations would mean for his and Bob Herman's theoretical work of the late 1940s and early 1950s, bridging "nuclear physics and mathematical cosmology," as he said, in predicting the CMBR.

Bob Herman became a lifetime friend and foil for my father. Their research had led to the prediction of the CMBR at about 5 K, and Herman would later state that this prediction was predicated on dad's work on nucleosynthesis. However, they observed with dismay that neither of the two 1965 papers mentioned their CMBR prediction, even though it had been published in major journals such as *Nature* and *Physical Review*. [9,13]

This began a difficult time for my father and Bob Herman. They had prepared early for this discovery, repeatedly trying to find somebody to search for the CMBR from the moment they predicted it. The mood around the house turned from elation to frustration. Much later, in 2008, in my dad's home files I looked into these events and made some discoveries of my own concerning events of the 1940s and 1950s. Working like a paleographer going through documents backwards in time, I'll start with observational cosmology by the Russians of the early 1990s and go back to a Canadian of the early 1940s. Then on the theoretical side I'll pick up the story in 1952 and work forward from there.

New Year's Greetings from Moscow: С НОВЫМ ГОДОМ

Among my father's papers, the first documents I examined were those he brought back from the International Conference on Physics Education that he attended in Toruń, Poland, in August 1991. I started here because it was his first invited *international* talk (a gratifying experience for him) and because of his Russian ancestry. At that time the Soviet Union was undergoing collapse, the Berlin Wall had come down, Germany was reuniting, and the Warsaw Pact was no more.

My father's plenary lecture was entitled "The Origins of the Hot Big Bang Model and Difficulties with its Acceptance." His copy of the program contained many handwritten notes. My attention was grabbed by the list of attendees, where Dad had ticked off names and circled the country of origin, especially for those who listed "U.S.S.R." I asked myself, "Why such attention to Soviet scientists?"

Although Russia was the homeland of Ralph Alpher (and Bob Herman's) fathers, I doubted that he was looking for our relatives. Any who remained in Russia when my paternal grandfather and his three brothers emigrated to the U.S. had not been heard from since the Josef Stalin era. I did not recognize any names, but I found an answer in my dad's files of old mail—and it was relevant to cosmology.

Alpher and Herman were often criticized for not convincing any radio astronomer to make the observation of the CMBR. Radio astronomy had not reached prominence between 1948 and the mid-1950s. Nevertheless, across the years Alpher and Herman tried repeatedly to find a radio astronomer to search for the CMBR.

At least through 1955 they were told it could not be done (too cold, too much error). I would suggest that radio astronomy was simply too new for anyone to risk much valuable radio telescope time on speculative work—at least here in the U.S. However, radio astronomy evidently progressed in the Soviet Union during the 1950s. [19,20] My dad and Bob Herman were perhaps the first U.S. physicists to recognize the significance of the cosmological research being conducted during the late 1950s by Soviet physicists.

In 1964 two Russian physicists, Igor D. Novikov and Yuri A. Zel'dovich, sent a New Year's card to my dad at the Lab (see Figures 3 and 4). In English they wrote "Best wishes for the New Year." That same year Novikov and A.G. Doroshkevich wrote a paper suggesting that the CMBR, *predicted in 1948 by Alpher and Herman, could and should be observed*. They had repeated the calculations and believed the technology then existed to make the measurement. [14,15] Much later Novikov would state in one of his popular books, translated into English, that it *had* been observed in 1957—in the U.S.S.R.!

Igor Novikov recalled that in late 1983 he received a telephone call from Tigran Shmaonov of the Institute of General Physics in the Russian S.S.R. Shmaonov told him that while working as a postgraduate in the 1950s, along with radio astronomers S.E. Khaikin and N.L. Kaidanovsky, with a horn antenna similar to the one used by Penzias and Wilson, he measured 3.2 cm radio waves coming from space. Shmaonov's results were reported in his 1957 doctoral thesis, and published in a paper in the Soviet journal *Pribory i Tekhnika Eksperimenta (Instruments and Experimental Methods)*. [14] Shmaonov concluded that "The absolute effective temperature of radiation background.... appears to be 4 ± 3 K." Alpher and Herman went to the extent to verify Shmaonov's work themselves. [21] Novikov states that their antenna could not have been as sensitive as that at Holmdel, New Jersey. Nevertheless, *the first radio astronomical observation of the CMBR may well have been made in 1957, less than 10 years after it was predicted, and documented in a Soviet physics journal*. Others suggest the French scientist LeRoux observed the CMBR even earlier, in 1954. [22]

Novikov's written history of the CMBR, which included the work of Alpher and Herman, delved back to the 1940s, to work by Walter S. Adams [16] and the Canadian Andrew McKellar. [17] Observational astronomical research during the 1940s and 1950s in the U.S. focused primarily on spectral analysis of elements and simple molecules in stars and interstellar space. McKellar's 1941 paper interpreted "spectrographic observations by W.S. Adams" of a nebular gas cloud, including a study of CN lines that appeared due to the molecule's rotational states. McKellar calculated "that the 'Rotational' temperature of interstellar space is about 2 K."

The *Zeitgeist* of the time held that empty space should have a temperature of zero degrees, so the 2 K was thought to be the temperature of an interstellar gas cloud, and the findings received little notice. Today many cosmologists attribute the first detection of the CMBR, if unrecognized as such, to Adams and McKellar. Similarly, when Penzias and Wilson "found" the unexplained 3-degree noise using the Holmdel horn antenna, it was not really a "finding" until the Princeton group interpreted that noise as the CMBR signal. Dr. Edward



3, 4. Soviet envelope with stamps in which Novikov and Zel'dovich's greeting card was sent to Ralph A. Alpher at G.E. in 1964. The two Soviet Physicists had also done their own calculation of the CMBR. Paired in this figure is the inside of the greeting card, in which "Best wishes for the New Year" is handwritten in English on the left with their signatures in English. On the right is the original Russian Cyrillic for Happy New Year.

Wright, a longtime member of the COBE team, states that "it is an interesting historical anomaly that...the first observers of the [CMBR] were completely unaware of its cosmological significance." [18]

Given the Cold War and Space Race, could cosmology have been very high on the Soviet science agenda in the 1950s and 1960s? One might be inclined to doubt it. Five years after Sputnik, the U.S.S.R. was setting up ICBM sites in Cuba, 90 miles from the U.S. mainland. At that time my father's daytime work was on atmospheric re-entry problems for such missiles (much of this work was funded by the U.S. Air Force, which also had its own re-entry systems projects; LTC C.J. Lyons, USAF-Retired, personal communication, May 15, 2009). However, much of his "avocational" time was spent staying current in cosmology. Similar mixtures of institutional vocation and individual avocation surely existed among Soviet physicists as well, despite national agendas.

The 1952 Yerkes Conference: Radio Astronomy Remains in the Shadows

In 1952, my dad, Herman, Gamow, and Follin attended a conference of 52 physicists, chemists, geologists, and astronomers, the "Conference on the Abundances of the Elements," sponsored by the University of Chicago and the National Science Foundation, and held

at Yerkes Observatory in Wisconsin. Many prominent scientists in astronomy, geology, chemistry, physics were among the attendees, including Subrahmanyan Chandrasekhar, Maria Goeppert-Mayer, Edward Teller, Gerard P. Kuiper, Harold C. Urey, and Andrew McKellar.

Cosmology had created theoretical problems, such as: Where did the relatively rare heavier elements come from? Found among my Dad's documents was a 34-page paper, promulgated after the conference, with commentary from each presentation. I was immediately impressed by the paper's thoroughness and by Dad's extensive notes.

At the 1952 Yerkes conference, three days of sessions were divided among astronomy, chemistry, geology, and physics. The geologists' and chemists' presentations focused primarily on terrestrial and asteroid element abundances. Andrew McKellar chaired the first morning session on astronomy, which focused on elements and compounds produced in stars. Dad's voluminous notes suggest that he was looking for information relevant to nucleosynthesis. Having predicted with reasonable success in 1948 the relative abundances of hydrogen and helium in the early universe, my dad and his colleagues were concerned about the heavier elements beyond hydrogen and helium. Cosmologists were troubled with some problems with the neutron-capture theory at masses 5 and 8 which Fowler later helped solve through a triple-collision process.[19] At the end of 11 pages of the 1952 handwritten conference notes, my dad wrote: "...heavy elements needed as 1% of all mass.... Need 20-100 times more [star] deaths than now observed. Maybe higher death rate earlier."

Dad's notes comment on the seeming lack of deuterium anywhere in the results of McKellar and others. A small amount of deuterium would emerge in the primordial nucleosynthesis, but inside stars deuterium is produced and subsequently destroyed as an intermediate state in a sequence of nuclear reactions. Among most of the papers, the statistical errors reported were sometimes staggering—from 20% to as much as 40 and 50% in some presentations. These error rates would surely discourage anyone from thinking that contemporary methods were sensitive enough to measure CMBR at the low black-body temperatures predicted by Alpher and Herman.

Alpher, Follin, and Herman presented the first paper on the formation of the elements, titled "Initial Conditions in the Expanding Universe and the Formation of the Elements." They referred specifically to "the expansion and cooling" necessary to explain light-element abundance under the neutron-capture model in their presentation. Gamow's presentation was titled "General History of the Expanding Universe." Maria Goeppert-Mayer's presentation, "Origin of Elements," was sandwiched between the other two. Her presentation assumed a *cold* "ylem" in contrast to the hot "ylem" of Alpher and Gamow, *et al* (Alpher had resurrected an old word *ylem*, pronounced *ī-lēm*, defined in Webster's Collegiate Dictionary as the primordial stuff from which the universe was created. The $\alpha\beta\gamma$ paper assumed a hot ylem of protons, neutrons, and electrons.)

Along with others who criticized the "hot big bang theory," Meyer concluded that a "cold ylem" could not explain "the large abundance of hydrogen and light elements." (I can picture George Gamow on the floor

laughing.) Foreshadowing the work on stellar nucleosynthesis of Fowler, Hoyle, and the Burbidges to come in 1957, she suggested there might be *different processes* accounting for the light and heavy elements. Strangely, although dad's copy of the program contains many handwritten notes describing the names, follow-up comments, and questions of attendees at each session, they indicate no questions or comments about the cosmology talks. If much interest in cosmology was present at the conference, it is not obvious in the historical record.

Fast Forward to 1978

The 1978 Nobel Prize in Physics was awarded to Arno Penzias and Robert Wilson for their detection of the CMBR. In 1978 when my dad happened to be nearby at Rutgers University giving a colloquium, Penzias asked dad to bring him "up to speed" for his upcoming Nobel lecture. My father spent more than a day doing so. In his published Nobel address, Penzias highlighted Novikov's work as the first mention of the CMBR as a *detectable* phenomenon (*sic*; Penzias' italics).[23] There were no references to my Dad's publications from 1948 onward, or of the efforts of Alpher and Herman to have the CMBR measured.[24] In contrast, Novikov and Zel'dovich had purposely announced themselves to my Dad in 1964. Novikov was aware of the 1940-41 observations of Adams and McKellar, with their potential meaning, as well as my dad's work.

In fairness to Penzias, Wilson, and their colleagues, they were in good company with most theorists and experimentalists, who missed the significance of a considerable amount of previous cosmology work. Gamow, Alpher, Herman, Fowler, Novikov, Zel'dovich, and other pioneers in cosmology had found their friendliest outlets to be physics and astrophysics journals rather than astronomy journals. Indeed, Gamow worried that their novel combination of theoretical nuclear physics and mathematical cosmology might be too speculative for the editor of the *Astrophysical Journal*. [25] Ralph and Bob were establishing a paradigm whose language was better understood by physicists.

Both dad and Bob Herman carried a code of ethics whereby the *manner* in which one does science is as important, or more important, than what one actually *finds*. I heard this mentioned at Herman's kitchen table more times than I can count, from 1985 to 1996. In any graduate program, the dissertation proposal typically encompasses a "high, wide and deep" search of the literature relevant to a subject before proposing one's own ideas as novel research. Why did this apparently not happen with Penzias and Wilson, and the Princeton group they consulted, concerning the history of the CMBR?[26]

To this day, attributions to the work on nucleosynthesis and the CMBR are still sometimes made entirely to George Gamow or "to Gamow and his students Alpher and Herman." [27] I believe there are two reasons for this. Merton's "Matthew effect" is the interpretation favored by my father. The Matthew effect says that an innovation is usually credited to its proponent who



5. Ralph A. Alpher (center), Robert Herman (right), and the author (left) take a break in Herman's living room in northwest Austin, Texas, 1994.

happens to be the most famous.[28] Also, the abrupt, accidental “discovery” of the CMBR by Penzias and Wilson appeared to many as a “break” from what had gone before.

Alpher and Herman have also been criticized for “abandoning cosmology” by “going into industry.” A citation search from 1955 through 1964 clearly refutes this, and even “academic” scientists occasionally get a day off for “consulting.” No less a theoretician than Albert Einstein consulted for the Naval Ordnance Laboratory (NOL) during the Second World War; at various times Gamow was a consultant to NOL, JHUAPL, and Los Alamos; and Arno Penzias and Robert Wilson worked in industry (Bell Labs) when they detected the CMBR![29]

In later “historical” papers, Peebles and his colleagues lament that they had *no reason* (my emphasis) to look further back in the literature at the time of their published July 1, 1965, interpretation of Wilson and Penzias’ observation.[30] They state that they were made aware of Doroshkevich and Novikov’s 1964 paper at a 1968 meeting of the American Physical Society in Washington. Wilkinson and Peebles admit that when writing their history in 2000, they relied on the publications of Gamow and past “conversation and correspondence” with him.[31]

After the 1948 Alpher-Herman CMBR paper, George Gamow wrote several papers in which he tried to come up with his *own* number for the CMBR. He was often very far off, having good physical insight but worrying little about mathematical rigor, and made no reference to Alpher or Alpher and Herman’s earlier work, creating further confusion about the genesis of the core ideas behind the CMBR. Alpher and Herman, perhaps his closest colleagues, did not understand why he continued to fail to refer to their work but felt it would be discourteous to bring it to his attention. Even in Gamow’s own publications, he failed to “show his work” as to how he came to figures such as 20 K for the CMBR.[32] Be that as it may, these publications may have contributed to a “Matthew effect” in relation to Gamow.

My father collected Gamow’s books. I discovered in the pages of one of them a note on which he wrote of Gamow; “drive and interest mistaken for egotism.” Gamow’s reputation was well-earned, and Bob Herman and my dad felt he deserved more recognition as one of the great scientists of the 20th century. The three of them continued to collaborate all their lives. Even in the last year of Gamow’s life, they wrote another joint paper which appeared in 1967 in the Proceedings of the National Academy of Sciences.[33]

By 1967, Gamow himself became upset about the lack of acknowledgment of the early work done by his students and himself. With Gamow’s passing that year, it fell to Alpher and Herman to try and set history right about events between 1948 and 1965. They continued to give talks and publish reviews of the history of the “Big Bang”[34] while maintaining current knowledge. They intended no offense to others, but provided voluminous references with their explanations of how their work fit into the history of expansion theory first proposed in 1922 by Alexander Friedmann, who had been Gamow’s mentor at the University of St. Petersburg.

Academics at Last!

After he retired from G.E., my dad became distinguished research professor of physics at Union College, and administrator of The Dudley Observatory



6. Photograph of Ralph A. Alpher taken in the early 1940s (about age 20) when he had begun working as a junior physicist at the Carnegie Institution’s secret Section T. His beginning work and later notoriety as a big bang theorist were several years ahead of him.

in Schenectady, New York. These roles began a new period of obvious enthusiasm for him. It put him, finally, in the academic community. The Dudley Observatory was founded in 1852 when Albany aspired to create a National University.[35] It also became an important part of my dad’s professional life. As board member and administrator, his affiliation with Dudley Observatory spanned four decades. His role as its administrator fit Ralph Alpher to a “T.” He was responsible for reviewing research grants and participating in the daily routines, including presenting science to the public, an important part of the observatory’s mission.

In 1985 I moved to Texas. On the same day I started my first “academic” position at the University of Texas Medical School in Houston, my father became distinguished research professor of physics at Union College. Bob Herman had retired from General Motors and took a position at the University of Texas at Austin in 1980. In Texas I began to develop a valuable friendship with Bob Herman, and to reflect further on my father’s career. My father, Bob, and I spent much time together at the Herman residence (see Figure 5).

Bob quickly became a personal friend and valued adviser to me. Those old saws that “you should have won the Nobel in physics” and “you guys did it all” were frequently brought up, and *what to do about it* was discussed, sometimes at Herman’s insistence, but both men continued to believe that in science, a nonpolitical meritocracy could exist. Science was a place where mankind’s venal nature and narcissism could and should be overcome.

In this regard, both men saw their return to academia as a hopeful time. Dad and Bob Herman spoke at a historical symposium on the subject in 1987 at a meeting of the American Physical Society.[36] By 1993, when they were awarded the Draper Prize at the National Academy of Sciences, Herman remarked sardonically that the prize indicated that “if you wait long enough, something good will happen.”[37] In 1988 they co-authored a retrospective cover story for *Physics Today*. [38] As they continued to publish retrospective histories, they hoped that their affiliation with academic institutions would help lead to the recognition *and correction* of errors in big bang history.

During the 1990s, more “histories” and “reflections” on the early days of cosmology appeared in books and journals. However, it seems their mid-career affiliation with industry continued to affect the perception by others of their professional identities. That perception led some to call 1965 the beginning of modern cosmology. Yet there *was* a body of original cosmological work, much of it authored by Alpher and Herman, documented in major peer-reviewed physics journals from 1946 through 1955.[39]

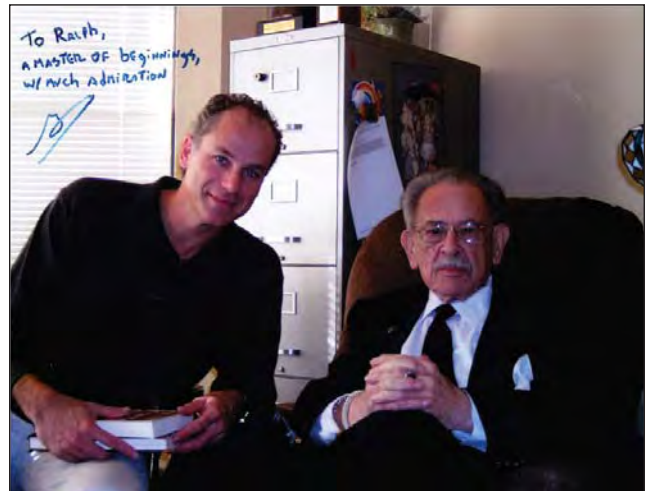
My dad was not the type of person to “blow his own horn,” but I found myself increasingly empathetic with Bob and dad’s experiences as time went on. After 1965, both men were disappointed about the neglect or mis-attribution of their work by the cosmology community, but Bob Herman appeared to me over the years as much more frustrated. He fared better with the National Academy of Engineering, which recognized him for his pioneering work on traffic flow and systems analysis.[40]

Some recognition of their work in cosmology did come their way in later years. In 1975 Alpher and Herman were awarded the first of several joint prizes, beginning with the Magellanic Premium of the American Philosophical Society, in Philadelphia.[41] The first source that my Dad considered as having the history of the prediction and discovery of the CMBR “basically correct” was Steven Weinberg’s 1977 book *The First Three Minutes*. [42] In 1978 Robert Jastrow sent to my Dad a copy of his new book, *God and the Astronomers*. In it Jastrow wrote, “To Ralph Alpher, who predicted one of the greatest scientific achievements of all time.”[43] Although neither man had been elected to membership in the National Academy of Sciences, Ralph Alpher and Bob Herman jointly received the Academy’s Draper Medal in 1993.

Unfortunately, Mr. Joseph D’Agnese, a journalist, somehow managed to coax an uncharacteristically negative remark from my father which was quoted in a 1999 *Discover* article, “The Last Big Bang Man Left Standing.” The *Discover* interview occurred when dad was first experiencing a number of difficult and degenerative medical conditions associated with aging. Sadly, the remark was widely disseminated and quoted (but *not* here). Of course, pulling out dramatic quotes is what journalists try to do, but such manipulative journalism has consequences. One major figure in this long drama recently expressed to me remorse at the implication of the D’Agnese article, thinking that throughout the last 40 years my father harbored negative feelings toward him. However, this was never the case. He *did* wonder about the *scholarship* of other scientists but did not bear them ill will personally. Negativity about such matters was not representative of my father, as I know from my intimate knowledge of his attitudes and feelings about these events throughout his life.

Alpher and Herman were featured prominently in the literature provided by NASA to those attending the launch of the Cosmic Background Explorer satellite in 1989. They were well acquainted with John Mather and George Smoot, who led the COBE effort. But I must confess that upon hearing of the announcement of the awarding of the 2006 Nobel to Mathias and Smoot for the COBE results, something changed in my father’s usually optimistic bubble. With four Nobels awarded pertaining to the CMBR, he seemed resigned that the last recognition related to it had been made. In my previous two articles in this journal, I have recounted how many of his accomplishments in other arenas, that would have resulted in recognition, remained hidden because the work was classified. I have come to believe this was the unique psychological world he occupied.

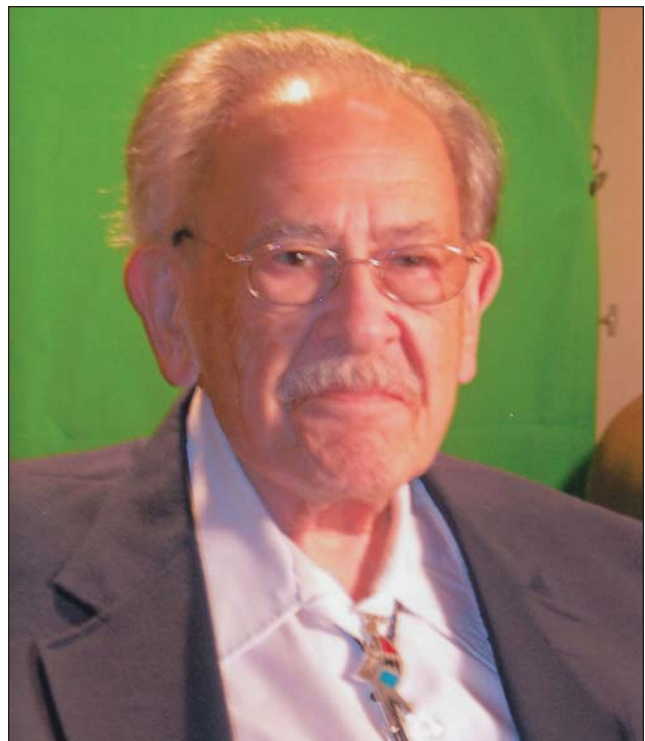
At Bob Herman’s insistence, my dad ultimately wrote a book. As he and Bob were sketching its outline and developing rough drafts of the opening chapters, Bob passed away in February 1997. But the book was published in 2001 by Oxford University Press, however with



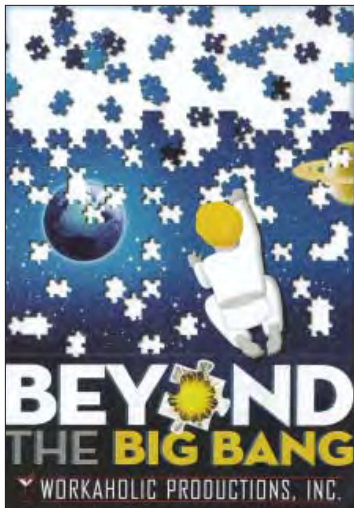
7. Photograph of Dr. Marcelo Gleiser and Dr. Ralph A. Alpher on the occasion of the interview for the Brazilian documentary “O Big Bang,” Tampa, Florida, December 3, 2005.

the title *Genesis of the Big Bang*. [44] My father insisted that Oxford list Robert Herman as co-author. Unfortunately, Oxford published it as a “trade” book rather than as a textbook. Because few were initially printed and no contract existed for a 2nd or revised edition, it has become a rare book, with limited use as a text and seldom appears on course reading lists. [45]

All of us knew my dad as an unpretentious scientist and community servant who did not seek recogni-



8. “Green screen” photograph of Ralph A. Alpher prior to the interview for the documentary “Beyond the Big Bang,” September 1, 2006. A variety of visuals were projected behind my dad’s image in the final documentary. Photograph taken by the author.



9. Poster advertising the documentary "Beyond the Big Bang" by Workaholic Productions, Inc., for the History Channel aired first on September 4, 2007. Used with permission from Workaholic Productions, Inc., and Matthew Hickey.

tion, but during the early 2000s, events led him to hope that his contributions to cosmology would not be forgotten. Other recognitions came, but not in forms he might have expected.

A Pertinent Award is Made Just In Time

In mid-2006, while serving as my dad's personal assistant, I caught in the mail a request from the White House for permission to conduct another FBI background investigation. (Because of his Russian origins and work on classified research, he had undergone a prior FBI investigation in 1952.) The 2006 request stated that my father was being considered for "some recognition" by the president. We heard nothing more for months and nearly forgot about it.

Richard M. Alpher, my first cousin, discovered about May 2007, through his contacts with the Department of Justice from where he had retired, that my father was to be awarded the National Medal of Science. This generated quite a swirl of interest and satisfaction within the family! The public press release was made in June, 2007. Despite all the erroneous recounting of the history of Ralph's contributions, we felt this might finally set the historical record straight. Happily, the award citation went further toward specifying his early accomplishments than anyone suspected.

Dad was hospitalized for the last six months of his life and was unable to attend in person the ceremony to receive the National Medal of Science at the July 27, 2007 presentation in Washington, D.C. I have been told such awards are rarely made under such circumstances. [46] However, close family members were there to represent him. Nominations and consideration for other awards had been made in the preceding years: the Wolf Prize in Israel, and the recently instituted Gruber Prize for Cosmology, [47] but the National Medal of Science was awarded in time for dad to enjoy it and appreciate its significance and the professional approbation.

It was not until the award of the National Medal of Science to Ralph A. Alpher that the prediction of the CMBR was correctly attributed to my father by the wider physics community. Astrophysicists today have started to offer my father and Bob Herman their due recognition. [48,49] Anticipating the CMBR forms an important prediction, based on solid theory in general relativity, thermodynamics, statistical mechanics, and nuclear physics. Both the nucleosynthesis foundation and

CMBR prediction built on it were singular achievements on their own merit. Historians of science [50,51,52] have demonstrated that it is sensible to see the period around 1948 as the *founding* of modern cosmology and astrophysics, not 1965. Neil deGrasse Tyson, who had a role in the National Medal of Science selection committee, also saw it this way. [53]

My dad and Bob Herman were not the only ones to be overlooked. They would say that quality work by Soviet theoreticians and radio astronomers was too long neglected. For that reason I went into some detail about this subject, and because of my dad's awareness of these players in the 1960s. Unfortunately, neglecting Soviet scientists was common during the Cold War.

Lauren Gunderson developed an award-winning play called *Background* about my dad's work. She learned about Ralph Alpher during her freshman physics course at Emory University, and "was so intrigued that I interviewed him and learned about his work in order to write the play....I took the context of his science (cosmology, of course) and used it to frame and structure the play. The play itself goes backwards chronologically, and ends with a hopeful nod to the future of science and Dr. Alpher's life. It was quite a silent thrill for me to see him win the National Medal of Science before he died." [54]

The play was developed at Emory University's Brave New Works play-development series and produced at The Essential Theatre in Atlanta, GA in 2004. Beginning with Ralph Alpher's 1978 heart attack, the play works through his life backward in time, echoing the manner in which big bang cosmology itself is sometimes studied. *Background* won the Artistine Mann Award and the Essential Theatre Prize for Best Play. With newspaper coverage, the play was also presented in a staged reading at Union College, to the delight of my parents. [55]

In the final three years of his life, my father was interviewed for two major documentaries. The first was produced by Federico Neves of Brazil and Dr. Marcelo Gleiser (see Figure 7) of Dartmouth University, also Brazilian, on December 3, 2005. The interview was broadcast across Brazil, in Portuguese, on TVGLOBO, the fifth largest broadcast network in the world, under the title *Ralph Alpher: Master of Beginnings*. [56] The broadcast generated an internet chat in which many stated that Ralph Alpher should have received worldwide recognition.

Matthew Hickey of Workaholic Productions, Inc., flew to Austin, Texas, on September 1, 2006, to interview my dad for a documentary entitled *Beyond the Big Bang* (see Figures 8 and 9). [57] Previously, Mr. Hickey had worked on the History Channel production "Modern Marvels." *Beyond the Big Bang* was aired for the first time about two weeks after Dad passed away. It received a CINE Golden Eagle award in 2008.

Ralph Alpher, Robert Herman, and George Gamow achieved another kind of fame in America through the television program "Jeopardy!"™ on its April 16, 2004, episode. The 27th question asked of 30 in the initial Jeopardy round that day gave the following clue: "In 1948, Gamow, Herman, and Alpher developed this 'large' cosmological theory." [58] The correct answer, for \$600, was "The Big Bang"—won by Stan Brown, a high school history teacher from Macon, Georgia, and the two-day returning champion. Perhaps the creator of this question, in putting George, Robert, and Ralph together

in this way, finally closed the book on the early history of the big bang. My father certainly enjoyed these moments of popular culture acknowledgment.

Early in the morning on August 12, 2007, Ralph A. Alpher passed away.[59] I was at his side and was overwhelmed at the extinguishing of this great flame. I am still awed at the magnitude of his life, something I cannot hope to equal.

He was fortunate to spend significant amounts of his professional and avocational time in *many* settings where science is done. I believe he saw academia, industry, and government laboratories, each one, as interesting and satisfying workplaces.

Ralph Alpher combined “nuclear physics and mathematical cosmology” in a way no one else had previously done. Most people familiar with the history of cosmology think he deserved to win the Nobel Prize. Such esteem from one’s colleagues shows the same respect as actually winning it. It has been both a privilege and a challenge for me to compress into three articles a summary of my father’s life. His advice to me was a priceless legacy: Find personal satisfaction, interest, and pleasure in your daily activities, and in your life’s work.

“Космологи Часто Ошибаются Но Никогда Не Сомневаются” “Cosmologists Are Often Wrong But Never In Doubt”

Lev Landau—1962

(Old fax that Ralph A. Alpher kept tacked to his bulletin board)

Acknowledgments

I am especially thankful for long discussions with my father, Ralph Asher Alpher, and my friendship with his long-time friend and colleague, Robert C. Herman.

I have come to know many extraordinary people through their relationships with my dad, for which I am grateful. I particularly recognize Peter Cannon, Martin Harwit, Igor Gamow, Ivar Giaever, Marcelo Gleiser, Robert Herman, Bob Johnson, Philip Kosky, Kathy Mead, Charlie Muckenfuss, Federico Neves, Matt Hickey, Paul Struhsaker, Neil deGrasse Tyson, James van Allen, Samuel Wait, Don White, and Robert Wilson. Each one offered some particular insight into my father’s career, approach to science, personality, and humanity.

Thanks to the staff of the National Archives (Archives II where post-1940 documents are kept), who were also very helpful during a research visit to College Park, MD, in October 2004. Norman Alpher, Deanna Alpher, and Rita Alpher assisted this intensive effort. I am grateful to Spencer Weart of AIP and John Payne for helpful advice. Melanie Brown of the Neils Bohr Library at the American Institute of Physics graciously and patiently helped me obtain 1987 tape recordings of talks by dad, Bob Herman, and others. Marie-Louise Chaix at EDP Sciences and Clarette Tupper at *Annual Reviews* facilitated access to journals. Dr. Samuel Wait of Rennselaer Polytechnic researched my dad’s involvement with RPI.

To Federico Neves, Marcelo Gleiser, and Matthew Hickey we owe the final two videotaped interviews of Ralph Asher Alpher. During these long interviews, Matt Hickey was particularly sensitive and well prepared to interview my dad. His entire documentary reflects his personal unique and masterful approach. I thank you especially for that, and your friendship, Matt.

Thank you, Lauren Gunderson, for taking the time and interest to invest part of your career in *Background. Radia-*

tions editor D.E. Neuenschwander contacted her for additional information.

For great expectations I thank my committee chair at Vanderbilt University, Professor Richard L. Blanton. My esteemed colleagues, friends, and confidantes Dr. Gerard Connors, William P. (Bill) Henry III, Ronald G. Presswood, Ralph Belknap Baldwin, James van Allen, Tatyana Zayeva, and LTC C.J. Lyons, USAF-Ret. Have been most supportive during this a long period of intensive work on this series of papers for *Radiations*. Thanks to *Radiations* editor Dwight E. Neuenschwander, an aficionado of my dad’s work, who valued the unique opportunity to publish my recollections and results of years of research into my dad’s career and life.

The ultimate responsibility for the content and interpretations in all of these papers rests with me. I welcome knowledgeable comments, corrections, or documented information pertaining to my three articles (www.ralphalpher.com). I launched this website in 2004 for my dad, which has now reached over 100,000 “hits.” I now leave it to historians of physics to reach their professional conclusions. They might start with Frank Levin, Stephen G. Brush, and Helge Kragh, who are among the expert interpreters of this amazing history. The reader can expect to find further papers concerning Ralph A. Alpher’s remarkable life and career from this author in the future. [50-52]

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Photographs, diagrams, and document scans presented in this and the previous two papers in this series are the sole property of the copyright holder, Victor S. Alpher, the Executor of the estate of Ralph A. Alpher, except where specifically noted. *Reproduction by any means, or storage of these materials in a retrieval system of any form, or transmittal in any form or by any means—electronic, mechanical, photocopy, recording, scanning, digitizing or other—except for brief quotations or mention in articles or reviews, without prior written permission of the copyright holder, is strictly prohibited. All rights, international and otherwise, are thereby absolutely reserved.*

[1] Marateck, S.L., *Physics Today*, **61**, September 2008, p. 12.

[2] Herman, R., “The Prediction of the Cosmic Background Radiation,” in *The George Gamow Symposium*, sponsored by The George Washington University and the Carnegie Institution of Washington 12 April 1996, *Astronomical Society of the Pacific*, **129**, 71-83, Edited by E. Harper, W. Parke, and D. Anderson.

[3] The first two articles in this series were Part 1: Alpher, V., “Ralph Asher Alpher—Before the Big Bang,” *Radiations*, Spring 2008, pp. 5-10; Part 2: Alpher, V., “Ralph A. Alpher’s Early Career: What Kind of Physicists Were They?,” *Radiations*, Fall 2008, pp. 6-14.

[4] Alpher, R. Bethe, H., Gamow, G., “The Origin of Chemical Elements,” *Phys. Rev.* **73**, 803-804 (1948).

[5] Gamow did this with Bethe’s permission and the understanding that Bethe would be listed “in absentia” but that caveat did not appear on the published paper, evidently an editorial decision. This did help fund a trip for Bethe to D.C. and a position on my father’s dissertation defense committee.

[6] Kaku, M., “Echo of Genesis,” *The Wall Street Journal*, October 4, 2006, p. A14.

[7] Gamow, G., “Expanding Universe and the Origin of the Elements,” *Phys. Rev.* **70**, 572-573 (1946).

[8] Gamow, G., “The Evolution of the Universe,” *Nature* **162**, 680 (1948).

[9] Alpher, A. and Herman, R., “Evolution of the Universe,” *Nature* **162**, 774 (1948).

[10] Alpher, R.A. Fiske, M.D. and Fearn Porter, B. “Physics Manpower: Present and Future,” *Physics Today* **33**, 44-53, Jan 1980.

[11] Penzias, A. and Wilson, R., “A Measurement of Excess Antenna Temperature at 4080 Mc/s,” *Astrophys. J.* **142**, 419-421 (1965).

[12] Dicke, R.H., Peebles, P.J.E., Roll, P.G., and Wilkinson, D.T., “Cosmic Black-Body Radiation,” *Astrophys. J.* **142**, 414-419 (1965). The Dicke *et al.* paper *does* mention the $\alpha\beta\gamma$ paper,

Ref. 4, and a 1953 nucleosynthesis paper by Alpher, Follin, and Herman, *Phys. Rev.* **92**, 1347 (1953), but not the CMBR prediction paper, Ref. 9.

[13] e.g., Alpher, R.A., Follin, J.W., Jr., and Herman, R.C. "Physical Conditions in the Initial Stages of the Expanding Universe," *Physical Review*, **92**, 1347-1361 (1953).

[14] Novikov, I.D. *Black holes and the Universe*. V. Kisin, Trans., Cambridge, UK: University of Cambridge Press, 1984.

[15] Doroshkevich, A.G., & Novikov, I.D., "Mean Density of Radiation in the Metagalaxy and Certain Problems in Relativistic Cosmology," *Soviet Physics-Doklady*, **9**, 111-113 (1964).

[16] Adams, W.S., "Some Results with the Coudé Spectrograph of the Mount Wilson Observatory," *Astrophysical Journal*, **93**, 11-23 (1941). Dr. Adams was the Director of the Mt. Wilson Observatory. As far as I could find, the first refereed journal citation of Adams' work as having anything to do with CMBR (using the SAO/NASA ADS Astronomy Abstract Service) was in 1966, by Patrick Thaddeus and J.P. Clouser in *Physical Review Letters*.

[17] McKellar, A., "Evidence for the Molecular Origin of some Hitherto Unidentified Interstellar Lines," *Publications of the Astronomical Society of the Pacific*, **52**, 307, 187-192 (1940), see page 192; *Pubs. of the Astronomical Society of the Pacific*, **53**, 233-235 (1941).

[18] Wright, E. L. "Cosmic Microwave Background." <http://www.astro.ucla.edu/~wright/CMB.html> (downloaded 31 December 2008). On the first page, Wright has a two-dimensional diagram of a theoretical "black box" that will produce blackbody radiation. I have one that my father had built many years ago to demonstrate this phenomenon.

[19] Greenberg, J., "A Conversation with William A. Fowler—Part II," *Physics in Perspective*, **7** (2), 165-203 (2005). Basel: Birkhäuser-Verlag. Fowler mentioned Novikov and Zel'dovich in this 1985 interview. Regarding Soviet physics, he states: "Theoretical, they're very good; tops in mathematics, very good in theoretical astrophysics. Zel'dovich is one of the really great ones. Ginzburg, Novikov—in theory they're fine. But, boy, not only is their experimental work third-class, but they just do wrong things" (harangue continues, p. 199). Perhaps this is the reason that Novikov put down their horn antenna in comparison with the Holmdel Horn of Penzias and Wilson. This may be one of the reasons that Penzias and Wilson's publication received so much attention in 1965, but as Fowler noted, when the Soviets "put their mind to doing something, like building bombs or a space program, they can do it." (p. 199).

Fowler comments that it was "Suess and Urey in 1956 [who] showed that then, with neutrons, you could go all the way up to uranium and thorium. By that time, *we began to realize that nucleosynthesis was the thing...*" [6 p. 186, italics added]. Fowler was somewhat enamored with Gamow: "I have a famous quotation from one of his papers where he admits that the lion's share of the production of elements beyond helium had to be done in stars" (p. 180). Regrettably, I never met George Gamow.

[20] Parijskij, Yu. N., "Radio Astronomy: The Next 70-Year Step," in *Radio Astronomy from Karl Jansky to Microjansky*, L.I. Gurvits, S. Frey, and S. Rawlings (Eds.), EAS Publications Series, **15**, 479-486 (2005).

[21] Alpher, R. and Herman, R., "Big Bang Cosmology and the Cosmic Blackbody Radiation," *Proceedings of the American Philosophical Society*, **119**, 325-248 (1975). They also reported on their personal contact with Dr. Shmaonov in Alpher, R.A. and Herman, R., "Remembrance of Things Past: Some Recollections of the Development of the Big Bang Model," in *Unified Symmetry: In the Small and In the Large*. Commack, NY: Nova Science Publishers, 1994.

[22] Novikov, I., Ref. 14, pp. 130-131. Even Robert Dicke has speculated that the "Dicke radiometer" he created in the mid-1940s from spare military parts available cheaply *could* have made the observation. The popular British science writer Simon Singh states (without citation) that the French radio astronomer Emile La Roux also made this observation in 1955; see "*Big Bang. The most important scientific discovery of all time and why you need to know about it.*" London: Fourth Estate, division of Harper/Collins, 2004). Singh also states (without documentation) that they "lacked the determination, persistence and rigor that allowed Penzias and Wilson to discover the CMB radiation" (p. 433). Perhaps this is journalistic hyperbole,

but I have seen no evidence that Alpher or Herman lacked these qualities. My father documented the many places he and Herman presented their findings in hopes of attracting a radio astronomer to pursue it.

[23] Penzias, A.A. "The origin of the elements," Nobel lecture (8 December 1978), *Reviews of Modern Physics*, **51**, 430 (1979).

[24] It was about this time that my Dad suffered a heart attack. That event forms a crucial scene in the 2004 play of Ref. 55.

[25] Ref. 38, p. 26.

[26] Editor's note: For example, B. Parker, whose sources included telephone interviews, writes that "Dicke admitted later that it was an oversight. He had completely forgotten about Gamow and his students' work. Furthermore, Peebles, in making his calculation, had not checked the literature. He just assumed that no one had worked on the problem." Parker, B., *The Vindication of the Big Bang: Breakthroughs and Barriers* (Plenum Press, 1993), p. 120-121.

[27] *ibid.*

[28] Merton, R.K. "The Matthew Effect in Science," *Science*, **159**, 56-63 (1968).

[29] Vest, C.M., *The American Research University*. Berkeley, CA: University of California Press, 2007. By the age of the Internet, the distinctions of "research university," private sector, government agency, and other sources of funding were becoming blurred. Also, the "Classified" nature of research carried out in the public sector (e.g., state universities), as opposed to free-standing labs (such as G.E. Research Lab and Bell Labs), has made the distinction between traditional academia and "working in industry" practically meaningless. Yet these differentiations still affect membership in groups such as the National Academy of Science. See also Herbert I. Fushfeld's review of Vest's book in *Physics Today*, December 2007, pp. 57-58.

[30] Wilkinson, D.T. and Peebles, P.J.E., "Discovery of the Cosmic Microwave Background," *Physica Scripta*, Vol. T85, 136-141 (2000).

[31] Wilkinson, D.T. and Peebles, P.J.E., *ibid.*, p. 141. Curiously, even after admitting they relied on Gamow for the early portion of their history, they nonetheless refer to R. A. Alpher and R. Herman's paper in the 1968 Gamow Memorial Volume "Cosmology, Fusion, and other Measures." It was actually "Cosmology, Fusion, and other *Matters*" (italics added by VSA).

[32] See Refs. 38 and 44.

[33] Alpher, R.A., Gamow, G., and Herman, R. "Thermal Cosmic Radiation and the Formation of Protogalaxies," *Proceedings of the National Academy of Sciences*, **58**, 2179-2186 (1967). Interested readers in the background of this publication should also see R.A. Alpher and R. Herman, "Calculation of Cosmological Parameters and their Approximations in the Standard Big Bang Model," in *Unified Symmetry in the Small and the Large 2*, Behram N. Kursunoglu, Stephen Mintz, and Arnold Perlmutter (Eds.), New York: Plenum, **95**, pp. 53-86. Late in life, Gamow appeared anxious to right in his own writing the perceived neglect of Alpher and Hermans. This led him to propose rapid publication of the Alpher, Gamow, and Herman paper in PNAS.

[34] E.g., Alpher, R.A., & Herman, R.C. "Remembrance of Things Past: Some Recollections of the Development of the Big Bang Model," in Perlmutter, A., and Kursunoglu, B.N. (Eds.), *Unified Symmetry in the Small and in the Large*. Proceedings of a conference held 25-27 January 1993 in Coral Gables, FL. Hauppauge, NY: Nova Science Publishers, 1994.

[35] Wise, G., *Civic Astronomy. Albany's Dudley Observatory, 1852-2002*. The Netherlands: Kluwer Academic Publishers, 2004.

[36] Alpher, R. A. Comments at the American Physical Society Joint Symposium of the Division of Astrophysics and the Forum for History of Physics (sound recording from Neils Bohr Library of the American Institute of Physics), 1987, April 21 and 22.

[37] Author's personal recollection.

[38] Alpher, R.A. and Herman, R., "Reflections on Early Work on 'Big Bang' Cosmology," *Physics Today*, August 1988, pp. 24-34.

[39] The problem of citation impact is relevant to the question of how the voluminous publications of Alpher and his colleagues in accessible journals such as *Physical Review*, *Reviews of Modern Physics*, and *Nature* could be "forgotten" or missed in

a literature search only a decade later. For a brief excursion into the development of the citation field, I would refer the reader to Hirsch, J. E., "An Index to Quantify an Individual's Scientific Research Output," *Proceedings of the National Academy of Sciences*, **102**, 46, 16569-16572 (2005) (This has come to be referred to as the "h-index"; Hirsch is a physicist.) For a more traditional approach to the problem, see Sharon G. Levin and Paula E. Stephan, "Research Productivity Over the Life Cycle, Evidence for Academic Scientists," *The American Economic Review*, **81**, 114-132, (1990). Levin and Stephan focus on the subspecialties of physics.

[40] At one of these meetings (usually held at Herman's kitchen table), I read one of Bob's early papers on traffic flow theory, which involved putting a traffic light in the middle of a town in Michigan that had had no traffic signals. This experiment involved observing the "clumping" of vehicles into convoys despite this not being drivers' goals. I mentioned that this study appeared to be quite similar to Applied Social Psychology—a comment on Bob's work that I never repeated, given his disappointing reaction to mine. I was pleased to find a striking commonality between this early work and applied psychology, but Bob was not.

[41] In the reference list for the paper following the award, a vast number of citations exist for publications in Russian, French, and German, as well as in translation to English, particularly from the period 1964 - 1975. This paper would be an excellent starting point for anyone researching the "early days of cosmology."

[42] Weinberg, S., *The First Three Minutes: A Modern View of the Origin of the Universe*. New York: Basic Books, 1977. This book has been subsequently revised a number of times. I met Steven Weinberg in 2005, at a meeting of the Austin Civil War Roundtable, where he at the time was on the board.

[43] Jastrow, R. *God and the Astronomers*, New York: W.W. Norton, 1978.

[44] Alpher, R. A. and Herman, R. *The Genesis of the Big Bang*. New York: Oxford University Press, 2001.

[45] Paul Butterworth, in a personal communication of 8 September 2008, gives this as the reason for not listing the book on the NASA COBE website. After this paper was submitted, the book re-appeared in a different format (www.amazon.com), without dustjacket.

[46] Dr. Martin Harwit, personal communication, 9 November 2008.

[47] *ibid.*, 8 November 2008.

[48] "April 1, 1948: The alpha beta gamma paper explains the origin of the elements," *APS News*, April 2008, p. 2.

[49] Turner, M. S. "From $\alpha\beta\gamma$ to Precision Cosmology: The Amazing Legacy of a Wrong Paper," *Physics Today*, **61**, December 2008. Turner, a prominent contemporary cosmologist, predicts that there will be more than the four Nobels already given for the CMBR to come (p. 6). He is highly critical of the "neutron capture theory." However, the importance of a paper is also measured by its inspiration for a program of further research, and the $\alpha\beta\gamma$ started an important conversation on nucleosynthesis, and inspired that program which continues to this day. It was, indeed, considerably revised by its authors as an all-encompassing explanatory theory for all of the elements—see Alpher, R.A., Follin, Jr., J.W., and Herman, R., "Physical Conditions in the Initial Stages of the Expanding Universe," *Physical Review*, **92**, 1347-1361, 1953. Sixty years later, one cannot write off the influence of the ideas and research promulgated by that novel paper and subsequent prediction of the CMBR. Turner correctly acknowledges that this 60-year-old paper led to a great deal of research, but even the early theorists saw the need for change. The Fowler interview (Ref. 19) suggests that he and his colleagues (the Burbidges, Hoyle, and others) were strongly influenced by the work of Alpher and Alpher and Herman to look for other sources for the heavy elements. Even the monthly official APS NEWS recognizes that the interpretation and controversy over the history of the formulation, discovery, and recognition of the CMBR is timely now—see Alpher, V.S. "Discovery in Physics Guided by Theory," *APS News* **18**, 5 (May 2009).

[50] Kragh, H. *Cosmology and Controversy, The Historical Development of Two Theories of the Universe*. Princeton, NJ: Princeton University Press, 1996; *The Construction of Cosmology as a Physical Science*. Paper presented at the Biennial His-

tory of Astronomy Workshops at the University of Notre Dame, 2007. I believe Kragh has made a breakthrough in understanding the 1948 - 1978, beginning with the publication of Ralph A. Alpher's doctoral thesis, and ending with the award of the Nobel Prize to Penzias and Wilson. Kragh's paper was retrieved on 12 December 2008 at <http://www.nd.edu/~histast4/exhibits/papers/kragh.html>.

[51] Brush, S. "How Cosmology Became a Science," *Scientific American*, **267**, 34-40, 1992.

[52] Levin, F., *Calibrating the Cosmos, How Cosmology Explains our Big Bang Universe*. New York: Springer Sciences+Business Media, LLC, 2007.

[53] Neal deGrasse Tyson, personal communication, 26 July 2007.

[54] Lauren Gunderson, private communication, 9 Feb. 2009, to the Editor.

[55] More about *Background* may be found at www.laurengunderson.com

[56] Dr. Gleiser wrote this as an inscription on a photograph taken by the author of him with my father in Tampa, FL on the occasion of the documentary interview for TVGLOBO on December 3, 2005. He then immediately presented a signed digital print of the photo to my dad. I don't think he was implying that my father was also present at the beginning of a new kind of science—as manifested by Section T of the National Defense Research Council at the Carnegie Institution—yes that was an important kind of beginning in government-funded scientific research (T.F. Gieryn, *ibid*; C.M. Vest, *ibid*).

[57] Hickey, M. (Producer and Editor, Workaholic Productions, Inc.), *Beyond the Big Bang*, documentary aired on the History Channel on September 4, 2007; taped September 1, 2006 in Austin, TX. Los Angeles, CA: Workaholic Productions, 2007.

[58] JEOPARDY! Long-running television game show hosted by Alex Trebek, April 16, 2004. Downloaded on 1/22/2005 from http://members.aol.com/ht_atdciago/jeoparchive/041604.html.

[59] Harwit, Martin. "Ralph Asher Alpher" (obituary). *Physics Today*, **60** (12), (2007). Dr. Harwit, an active distinguished physicist and emeritus professor at Cornell University, also referred to the "puzzling patterns" (his words) of late recognition of my father's groundbreaking and seminal work in cosmology (p. 68).

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