

*This paper commemorates the past year, 2009, in terms of two events championed by the scientific community: the International Year of Astronomy, and the bicentennial of the birth of Charles Darwin. The International Year of Astronomy has been described as a global effort . . . to help the citizens of the world rediscover their place in the Universe (IYA, 2010), while the various events associated with Darwin's bicentennial are aimed at promoting an increased understanding of how life on Earth has evolved, and ultimately, how humankind came to exist. (IDDF, 2010)*

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A common thread connects the exploration of our Universe, and the puzzle of our own existence. That thread is the subject of **origins**: how things got started, whether one is pondering the first human, the first cell, or the origin of the Universe itself. That connecting thread is also challenging, even intimidating to entertain in a brief paper. One is pondering, after all, the very biggest of Big Ideas.

As a meager step toward Parnassus, let me invite the reader to consider the late British astronomer Sir Fred Hoyle. Hoyle's life curiously embodies certain ideological conflicts around origins, and this paper uses his ideas as a vehicle to explore the deep connection between the Universe, and life itself.

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**Fred Hoyle's life** began in Yorkshire, in the summer of 1915, with the Great War underway and his father in harm's way. Hoyle senior would survive the conflict, but as a businessman he was undistinguished in the best of times, and often impoverished. In those humble times, there was no expectation that anyone, much less young Fred Hoyle would grow up to change the way people viewed the Universe. Cosmology was largely a topic for metaphysics or religion, and not a recognized field of scientific inquiry.

In fact, in the year Hoyle was born the strongest scientific statement most physicists were willing to make about the Universe's structure was to express a preference for mediocrity! **Copernicus** had famously argued you did **not** need to place the Earth at the center of the solar system to explain the observed motion of the planets. His book, *On the Revolutions of the Celestial Spheres*, demoted our planet from its pivotal cosmic position, and its impact on Western thought was such that the word 'revolution' was eventually also applied to political and social change, and not 'merely' the motion of heavenly bodies. (Davies, 2006)

Copernicus, of course, was correct: the sun, not the Earth, proved to be the center of the solar system. Perhaps more importantly, the general practice of assuming the **mediocrity** of the Earth's position proved liberating and fruitful for the field of astronomy. By the turn of the century, astronomers were inclined to extend Copernicus's insight: just as the Earth was not the center of the solar system, the

solar system was not the center of the Milky Way Galaxy, which most regarded as identical to the Universe itself. Earth's position was in no way favored or privileged, and this **Copernican Principle** still exerts a powerful influence on scientific accounts of the Universe because, in the same year Hoyle was born, something like that Principle must have inspired **Albert Einstein's** attempt to form the first scientific cosmology. (Rudnicki, 1989)

The former Swiss patent clerk had already made waves ten years earlier, the so-called 'miracle year' of 1905 in which he published, among other things, the **Special Theory of Relativity**. Einstein applied math originally developed to describe the geometry of curved spaces to thought experiments involving observers in relative motion. Such motion involves changes in both space and time, which are no longer conceptualized as separate phenomena, but as components of a four-dimensional space-time continuum. (Barrow, 2002)

But special relativity, despite being inspired by the math of curved spaces, still treated an observer's frame of reference as if it was embedded in a Euclidean space, with no curvature. Special relativity could not describe cases in which the frame of reference itself was being accelerated, as in the case of gravity, and this left Einstein dissatisfied and restless. (Einstein, 1920)

Einstein's eventual response to the problem, the **General Theory of Relativity**, was published when little Fred Hoyle had just reached his fifth month. General relativity fully embraces the idea that space really is curved, and explains the apparent force of gravity as due to the warping of the space-time continuum that defines the Universe. General relativity is thus a solution for the Universe as a whole, not just a set of special cases. There is no longer any privileged frame of reference, anywhere!

This is the Copernican Principle writ very large, in which there are no privileged observers in the Universe, and it is this last requirement that establishes "the theoretical basis of modern cosmology." (Davies, 2006). According to this understanding, what observers on Earth see when they look at the Universe should be pretty much what an observer in another galaxy might see: at sufficient scale, the Universe should be **isotropic** (having the same shape) and **homogeneous** (having the same sort of composition).

And this is precisely what Einstein was after: by the time Hoyle had reached his second birthday, Einstein had published a second paper showing how relativity theory could be used to generate a model of the Universe. There was just one little hitch! The original field equations suggested that the toy universe would not be static, but rather would be evolving over time: specifically, it predicted the expansion of space. This was a notion that Einstein and most of his contemporaries were not disposed to seriously consider: observational evidence for the claim had not yet appeared, and many found it philosophically repugnant. Einstein, for his part, saw that expansion implied a beginning to the present Universe, and this seemed to run counter to his own expanded sense of the Copernican Principle. (Davies, 2006)

After all, Einstein's theories had unified space and time into one continuum, and if there were no privileged locations in the Universe, there should also be no privileged times, either. (Bondi, 1960) A beginning to the present order seems at first glance to be the most privileged of moments, and an evolving, non-static universe? Well, it was just ugly, even disturbing. Einstein preferred a static, eternal Universe, worlds without end, or a beginning, Amen. To get the desired result out of his equations, the great scientist did something surprising: he introduced a 'fudge factor' called the '**cosmological constant**' (Weaver, 1987), which effectively provides a negative repulsive force to counter the predicted expansion, and keep the toy universe tidy, symmetrical and eternal.

Things began to go wrong with Einstein's static universe model even before it saw print in 1917. His model predicted a universe of matter without motion, but the Dutch mathematician **Willem DeSitter** had already shown Einstein that the same set of field equations could easily yield a universe of motion, without matter! (Weaver, 1987) Expansion remained possible, a prospect that provoked Einstein to reply, "This circumstance irritates me."

But the irritation had just begun. From the New World, came observational data increasingly at odds with a static model of any kind. In California, **Edwin Hubble** was employing the unprecedented power of the brand-new **Mt. Wilson 100-inch reflector**. While Fred Hoyle was discovering the joys of school truancy, Hubble showed that the spiral nebulae thought to lie along the rim of our galaxy were actually distant galaxies themselves, and that the 'island Universe' of the Milky Way we inhabit was just one of countless such objects, another demonstration of Copernican mediocrity.

This was bad for both the Einstein and DeSitter models, as their toy universes could not account for the increased scale of the Universe as measured by observation. By the time Fred Hoyle was eleven, both model-builders had waved the white flag. Hoyle, as I hinted earlier, wasn't much of a student in grammar school, but around this time (1927) he discovered a copy of *Atoms and Stars* in the town library. The book was a popularization of astronomy by **Sir Arthur Eddington**, at that time arguably the best-known scientist in Britain due to his role in confirming predictions of Einstein's theories. Hoyle devoured Eddington's book, at the very same time that Einstein, Eddington and others were attempting to digest more difficult news from America. (O'Connor and Robertson, 2006)

It had been known for some time that astronomers at the Lowell Observatory in Arizona had been reporting shifts toward the longer (red) wavelengths in the spectra of the same spiral nebulae. At Mt. Wilson, Hubble and his assistant **Milton Humason** carefully correlated similar data on '**red shifts**' with their distance data, and found a striking relationship: the more remote the nebulae, the greater the 'red shift' as with the well-known Doppler effect heard from the horn of a passing car, the shift in frequency meant that the object in question was moving away from the observer. In this case, all the objects were galaxies, and they were all moving away from each other, or to speak more precisely, the space between them was growing. (Hubble, 1937)

The universe, it seems, had spoken. To Eddington, the message was clear. By 1932, he could write that “we must reconcile ourselves to this alarming rate of expansion, which plays havoc with older ideas as to the time-scale.” (Eddington, 1932) And, remarkably, this is what the astronomy community did. Within a very short time, the majority of astronomers embraced the revolutionary concept of an expanding universe, their minds perhaps already prepared for change by the series of shocks produced by Einstein’s theories.

Einstein himself, perhaps a bit more stubborn, made it his business to travel to America in a time where such a journey was quite a venture. He made the trek up to Mt. Wilson, took a peak through the 100-inch reflector, and took pictures with Hubble and other luminaries from **Cal Tech**. But at the end of the day, it was clear the ‘red shift’ data had convinced Einstein as well, who ruefully concluded that his ‘cosmological constant’ was “the biggest blunder” of his life. Einstein could at least draw some consolation from the fact that another solution of his original field equations by the Belgian priest **Georges Lemaitre** had produced a ‘toy universe’ that agreed with the available data, and that his theory was the baseline for modern cosmology.

While all this was going on, the fresh-faced Fred Hoyle, his mind awakened to the glories of natural philosophy, had found his ambition. In 1933, Hoyle entered Emmanuel College, Cambridge, intending to read for a degree in science. (O’Connor and Robertson, 2006) It was immediately obvious to his tutors that Hoyle’s North country education was woefully deficient in mathematics, and so he was encouraged to study math as an undergraduate, with the idea that he would later switch to science after correcting his deficiencies. In a move typical of his personality, Hoyle quickly decided that he would not only read for a degree in math, but (against the advice of his teachers) that he would enter the college’s most prestigious competition, the **Math Tripos**. In effect, he would be cramming two years of mathematics into one year. (Mitton, 2005).

What a cheeky young man Fred Hoyle was, to essay such a course with so little preparation! His hard-scrabble North country background had fostered an independence of spirit that served him well here, and in fact is one of the defining features of Hoyle’s scientific career. Speaking for himself, Hoyle could write that “you have to have . . . a sense of obstinacy inside, because if you don’t, you’re not going to go against the crowd, and if you don’t go against the crowd you’re not going to have any real success.” (Gregory, 2005)

It is a measure of Hoyle’s drive and ability that he not only passed the first stage of the Math Tripos, but decided to remain in the mathematics program rather than switch back to the sciences. He was aware that Cambridge faculty like Eddington and **Paul Dirac** had begun as mathematicians, and reached meteoric heights as theoretical physicists, and he saw no reason why a Yorkshire lad with limited means could not aspire to the same. Indeed, he would end up publishing some of his first papers on nuclear physics as Dirac’s research student! (Gregory, 2005)

Hoyle's improbable hurdling of Britain's academic gateposts, and his subsequent impact on the world of physics can be laid in part to his personality, which above all was manifested in his blunt manner of expressing his views, traits which have been said to be characteristic of **Yorkshiremen** in general. An East Yorkshire clergyman has described his own people with words that seem almost prophetic where Fred Hoyle is concerned:

*"The Yorkshireman has, no doubt, a way of speaking his mind very freely, and telling you what he thinks, even if his opinion be never so contrary to your own; what others would let you know by an innuendo or side-wind, he makes known to you without the slightest reserve or disguise.â. (his) independence is of the most healthy kind; it is not only a good thing in itself but it also fits a man for making his way in the world, and struggling with the battles of life. And yet I have very often heard this very quality spoken of as if it were something to be deplored. 'You Yorkshiremen are such an independent lot'; 'I never came across such independent, ill-mannered people'; 'They are so independent, they don't seem to care for anybody' ; - these are the kind of remarks I have had to put up with in speaking with strangers about my fellow Yorkshiremen. This does not hurt us much; they do not understand us, that is all."* (Morris, 1911)

As I hope to show, this is not completely true where Hoyle's ideas are concerned, and during the course of his career Hoyle's scientific reputation was both built up and undermined by his blunt independence. But, in 1939, there was little hint of that turmoil ahead for the 24-year-old Hoyle, who had just won himself a teaching fellowship.

Instead, Hoyle was occupied by his career path. The political situation with Germany was deteriorating, and by March of that year Hoyle became aware of the possibility that nuclear physicists like himself would be enlisted to make weapons. Hoyle had no interest in weapons development, and he had also recently absorbed a breakthrough paper by **Hans Bethe** that explained that stars produced energy by the fusion of hydrogen. (Bahcall, 2000) By the summer of 1939, Hoyle had decided to switch from applied nuclear physics to astronomy, but his defection to the heavens would not stop Hell on Earth. (Kragh, 2006)

The long-feared war would come anyway. Hoyle viewed the conflict as a personal disaster that would "destroy his affluence and disperse his colleagues" (Mitton, 2005), and would later write that the war "would swallow my best creative period, just as I was finding my feet in research." (O'Connor and Robertson, 2006)

Critical biographers may not agree with Hoyle's self-assessment. As feared, he was enlisted once the war began. But, being relatively unestablished, he was not among those British physicists asked to collaborate with the Americans on problems of beta decay or neutron capture to build weapons. Instead, he was unglamorously packed off in the fall of 1940 by the **Admiralty Signals Establishment**, or ASE, to a building known as "**Hut No. 2**", in the south coast of England.

The ASE was in charge of developing Britain's radar systems, but (true to form) Hoyle was an outsider. The project was already underway and dominated by engineers, and the project managers had little idea what to do with a mathematician with no knowledge of radar. Hence, Hoyle was essentially left to his own devices in Hut No. 2, where he was joined by a recent Cambridge mathematics graduate, Cyril Domb. (Gregory, 2005)

Hoyle's initial response to the situation was to encourage the junior Domb to do the bulk of any required calculations while he attempted to bring both of them up-to-speed on radar technology by poring through the available literature. (Schweber, 2002) Little progress was made. Hoyle, as his recollections attest, was adrift and looking for a challenge. In the spring of 1942, this pair was joined by two other outsiders: **Hermann Bondi and Thomas Gold**. Like Domb, Bondi and Gold were 'outsiders' in part because they were Jews, but also because they among the many foreign-born university students temporarily interred (in Canada!) as security risks. Bondi and Gold were eventually released with the understanding that they would go to work for the very establishment that had previously taken their liberty.

Like Hoyle, Bondi was a mathematical prodigy. Gold, on the other hand, had a strong background in mechanical engineering. The newly-configured quartet in Hut No. 2 quickly made serious progress in solving problems on radar ground clutter, and the trio of Bondi, Gold and Hoyle spent their off-duty hours debating new astrophysics. (Tucker, 2004) As outsiders, they felt free in that isolated wartime setting to apply serious thought to problems outside the mainstream. They were intrigued by Bethe's analysis of nuclear reactions in stars, and they felt free to dissent from the new prevailing wisdom that the universe was expanding. (O'Connor and Robertson, 2006)

Hoyle applied pressure to extricate himself from his Admiralty commitments before the war ended so he could pursue his newfound interest in **nucleosynthesis**, the formation of the elements from atomic nuclei. This was subtly related to the problem in cosmology, because any mature theory of the universe's structure would have to account for the abundance of the chemical elements. Stars, and indeed most of the 'ordinary' matter in the Universe is composed, chiefly, of the two lightest elements: hydrogen and helium. Bethe's 1939 paper had brilliantly explained the production of helium inside stars, but that left the other ninety-odd naturally-occurring elements unaccounted for. Where did all this elemental variety come from? Hoyle, true to form, saw this gaping hole as a chance to make his mark in a brand-new, wide-open, field, but he was also keen to revive interest in something like Einstein's static universe.

As a boy, Hoyle had listened to his wool merchant father wax enthusiastic about **Darwinian evolution**. Ever the contrarian, the young Hoyle had taken to arguing against evolution, and it is tempting to speculate that this may have led to a lifelong distaste for the idea that any system could fundamentally evolve. (Mencke, 2009) Hoyle, like Einstein before him, came to prefer a static, eternal Universe, worlds without end, or a beginning, Amen.

As such, Hoyle was inclined to think in terms not just of individual nuclear reactions, but in terms of cycles of reactions, that, cycling on, could continuously generate the observed abundances. Hoyle's 1946 paper, "The Synthesis of the Elements from Hydrogen" is the first outline of what will eventually be called *the theory of stellar nucleosynthesis*.

At about the same time, however, some of the nuclear physicists who had (unlike Hoyle) worked on the *Manhattan Project* were tackling the same problem from a different point of view, and they had an initial edge: the American military had pioneered the construction of the very first digital computers, in part to calculate the effects of an atomic blast. (Kragh, 1996) Now **George Gamow** and his colleagues would use these computers to simulate conditions in the early Universe! In their model, the raw material of the universe would begin as a sea of energetic particles at a near-infinite temperature. As the mass cooled and expanded, Gamow reasoned, the various elements would assemble as the particles captured neutrons, one-by-one. (Gamow, 1952)

Gamow's group was able to show that this approach, called *cosmic nucleosynthesis*, could account for the observed abundances of hydrogen and helium, but again (as with Bethe's 1939 model) the heavier elements remained mysterious. For example, there seemed to be no way to "cook up" particles with eight mass units in Gamow's scheme. (Fowler, 1983) But, there is a method to make a particle of mass eight, one that will figure heavily in this narrative: the so-called *triple alpha process*, which takes its name from the fact that it involves fusing not two, but three alpha particles (each with a mass of four) into a single carbon nucleus with a mass of twelve.

The process has two stages. In the first stage, *beryllium-8* is formed, which is highly unstable and tends to fall apart in just a tiny ( $10^{-17}$ ) fraction of a second. If beryllium-8 collides with another alpha particle prior to falling apart, however, it can become the highly stable *carbon-12, essential for life*. That was the good news. The bad news was that beryllium's instability limited the reaction rate. Hoyle struggled to conceptualize the possible reaction cycles, working largely on his own without the advantage of any computer to assist him. Like everyone else who had tried, Hoyle had failed to find a solution to the field equations that would permit a static, eternal universe.

At this point, we must accept a colorful but largely-unconfirmed recollection of Hoyle's as to a critical spark of inspiration. Thomas Gold had stayed with the Admiralty some time after the war ended, but in 1947 he, Bondi and Hoyle were reunited at Cambridge. Looking for amusement, the trio caught a matinee of a British horror film called "*Dead of Night*". (Mitton, 2005). At the end of the film, there is a plot twist, a ghost story that ends in the same way that it started. As Hoyle told it: "One tends to think of unchanging situations as being necessarily static. What the ghost-story film did sharply for all three of us was to remove this wrong notion. One can have unchanging situations that are dynamic, as for instance a smoothly flowing river." (AIP, 2010)

Matter and energy, of course, appear to be flowing through space-time: not static! Solutions to Einstein's field equations that were static, on the other hand, appeared to violate the conservation of energy. It was Gold who suggested a way around this dilemma: simply, that "the energy balance of the universe would remain stable if matter were being continuously created and destroyed in equal amounts." (Tucker, 2004). Bondi, who had a philosophical bent, instantly seized upon the fact that this could resurrect the sort of Universe sought by Einstein: there would be no privileged locations, or privileged times. (Bondi, 1960)

The requirement that the Universe be both *isotropic* (having the same form) and *homogenous* (having the same composition throughout) was labeled the *Perfect Cosmological Principle* by Bondi (1952), and formed the basis of the trio's '*steady-state*' theory. In these models, new matter is constantly being created in the void of space while the galaxies of old matter are dissipated beyond a cosmic horizon (McGraw-Hill, 1980). This was intuitively appealing in itself, but the key breakthrough that would make it possible to 'sell' the idea to other astronomers was provided when Hoyle worked out a solution to the field equations that was consistent with general relativity (Oxford, 1994).

Like Einstein, Hoyle ended up adding a term to the equations, but his was not a 'fudge factor' to square the model with the data, but rather one that naturally flowed from the model's assumptions. Hoyle described *the constant creation of new matter* as the result of a field of negative pressure which also drove the cosmic expansion, neatly solving two problems of cosmic structure with one stroke. By the end of 1948, Hoyle had published two papers outlining the new cosmology, and the 'steady-state' model was soon being widely discussed, and not just by scientists, but in the popular culture.

Part of the attention was due to the existence of a rival theory. By the end of 1948, Gamow and his colleagues had published their updated version of *the expanding universe model*, as well, with some impressive data where abundances were concerned. While only accounting for hydrogen and helium, Gamow was able to joke that his model was a success, since it accounted for 99 percent of the universe. (AIP, 2010). The British group, while not overwhelmed with supporting data, had an impressive theoretical basis for the new model and, if the truth were to be known, many sympathetic colleagues who had never warmed philosophically to the idea that the present order had a definite beginning. A very public vetting of two very different theories was in the works, and a public rivalry.

For Hoyle's part, his role as the public face of steady-state theory was amplified by his frequent appearances on the BBC, where his country accent, energy and plain-spokenness won favor with listeners. His most memorable performance on the wireless, without a doubt, was an off-hand treatment of Gamow's theory, which (according to Hoyle!) is "distinguished by the assumption that the universe started its life a finite time ago in a single huge explosion. On this supposition, the present expansion is a relic of the violence of this explosion. Now this **BIG BANG** idea seemed to me to be unsatisfactory even before detailed examination showed that it leads to serious difficulties." (Singh, 2004)

“This big bang idea!”. As science historian Simon Singh (2004) remarks, Hoyle’s remark was perceived as a “derisive comment, meant to be a glib phrase to explain what he thought was a rather poor theory. Even though he meant it as an insult, the name stuck. Ever since then we’ve called it the Big Bang theory, christened by its greatest critic.” For his part, Gamow (1952) replied that Hoyle’s steady-state theory “has so far failed to provide us with a satisfactory quantitative explanation of the observed abundances of chemical elements and is, in the opinion of the author, artificial and unreal.”

Gamow was not above sending press releases to public figures about why his views should prevail, and the matter became further clouded by prejudice when Pius XII declared that “big-bang cosmology affirmed the notion of a transcendental creatorà in harmony with Christian dogma.” It was a small step from there for uncritical thinkers to link the steady-state theory with (gasp) an atheist like Fred Hoyle. (AIP, 2010)

Needling tone aside, Gamow was on point when he noted that any successful theory had to account for the observed elemental abundance. Hoyle was certainly devoting his attention to the matter, in particular the tricky triple-alpha process. The previous year, the American physicist **Ed Saltpeter** had demonstrated the importance of the process at the Cal Tech radiation laboratory, (Barrow, 2002) and during a visit to the Pasadena facility in 1953, Hoyle had an insight that has been described as “a tour de force of modern astrophysics.” (Arnett, 1996)

Recall that in the triple-alpha process, the intermediate beryllium-8 was ridiculously unstable, passing in and out of existence in less time than it would take light to travel around the nucleus. The number of atoms that would ever make it to the second stage and become carbon was vanishingly small. (Arnett, 1996) Even worse, Hoyle realized, was that farther down the chain of nuclear reactions he envisioned carbon would be quickly consumed. There should be very little carbon in the universe, and yet, the abundant life of planet Earth revolved around the equally abundant and amazingly versatile carbon atom. There must, Hoyle thought, be a higher production of carbon than the models predict, because otherwise, life would not exist. He, Fred Hoyle, would not be around to make that observation! (Davies, 2006)

Casting about for an explanation, Hoyle thought about what he had learned about nuclear reactions studying the work of Bethe and others. He was aware that nuclear reactions now and then experience situations where their rates are greatly amplified. They are said to be “**resonant**” if the sum of the energies of the interacting particles is very close to the natural energy level of another, heavier nucleus. (Barrow, 2002) Reviewing the Cal Tech lab’s up-to-the-minute data on elemental abundance, Hoyle calculated the resonant energy carbon would need to have in order to achieve the desired reaction rate. He got a number (around **7.65 MeV**), but no one had seen a resonance at this energy.

Undeterred, Hoyle began badgering the good-natured lab director, **William Fowler**, who at that time was probably the world's leading experimental physicist where nuclear reactions were concerned. The Cal Tech team of physicists were "incredulous that a little-known British astronomer could breeze in unannounced and claim to know more about carbon nuclei than a leading group of U.S. nuclear experts." (Davies, 2006) But, Hoyle could be very persuasive, and soon convinced Fowler that perhaps the entire physics community failed to look in the right way for the missing resonance. (Barrow, 2002)

Fowler has said that he converted to Hoyle's theoretical approach a few days later, when an impromptu experiment yielded **a previously-undiscovered resonance at 7.656 MeV**, right where Hoyle had predicted! Fowler was so impressed, in fact, that he spent the next year on sabbatical in England to work with Hoyle, where the pair were joined by the husband-and-wife team of **Geoffrey and Margaret Burbidge**. (Fowler, 1983)

Further experiments showed that the reaction rates the group predicted by theory would actually occur at the energies found in red giant stars, and the group was also able to rule out any role in the synthesis of the heavy elements by Gamow's "Big Bang.". (Fowler, 1983) Cosmic nucleosynthesis was largely confined to a few light nuclei; it was the stars that cooked up the heavy elements. In 1957 the Burbidges, Fowler and Hoyle published a paper summarizing what they had learned about the reaction cycles. This paper, "**Synthesis of the Elements in Stars**", is one of the most famous scientific papers of the 20th century, and is typically referred to as "**B<sup>2</sup>FH**" (b-square-f-h). Carl Sagan's much-quoted phrase "we are all star stuff" is essentially a paraphrase of the paper's opening thesis. B<sup>2</sup>FH" established the field of nuclear astrophysics, and its influence is so great that in 2007 there was a widely-attended conference in that field to celebrate the 50th anniversary of the paper's publication. William Fowler would win the 1983 Nobel Prize largely on the strength of this paper. (B<sup>2</sup>FH", 2010)

But the Nobel would elude Hoyle. There were honors, amidst a growing sense of restlessness: the next year he was made **Plumian Professor of Astronomy at Cambridge**, the same post once held by Eddington. He would be knighted, and become **Sir Fred**. There would be other, significant papers in astrophysics with his name attached, and he would remain something of a celebrity his whole life. But his model was in for a shock, and his reputation, more so.

While stellar nucleosynthesis was a wonderful achievement, its successes did not prove the 'steady state' theory so much as it discredited aspects of Gamow's approach. Stellar nucleosynthesis explained the heavy elements, but Hoyle was forced to concede it could not account for the abundant, ubiquitous hydrogen that made up most of the universe. (Wagoner, Fowler and Hoyle, 1967) The continuous creation of hydrogen in the void of space was untestable, because the predicted rate of production in Hoyle's model was on the order of one hydrogen atom per cubic meter every billion years. (Barrow, 2002)

As time went on, an unlovely parade of facts slowly accumulated against the beautiful theoretical edifice of 'steady-state' theory. Hoyle had spent the war working on radar, but now **radar astronomers** were able to probe the universe at wavelengths much longer than visible light, and what they "saw" in 1963 was a terrible problem for Hoyle's theory: exotic objects called **quasars**, distant and extremely luminous, testified to a Universe whose past was neither isotropic and homogenous. (Hoyle, Narlikar and Wheeler, 1964) Hoyle famously feuded with the **Royal Astronomer Martin Ryle**, in effect claiming that Ryle was deliberately attempting to sabotage the 'steady state' model. An unpleasant episode, but the real shoe dropped the next year.

This time, it wasn't British radio astronomers giving Hoyle the vapors, it was American scientists working for the phone company. **Arno Penzias and Robert Wilson** were Bell Labs researchers, who in 1964 were working on a tower that contained a microwave antenna. During tests, they noticed a persistent hum at 7.35 centimeters. It was about one hundred times greater than ordinary radio noise in strength, and it was active 24-7, no matter how they tried to ground the apparatus or which direction they pointed the dish. Eventually, it became clear that this signal represented what is now called the **cosmic microwave background**, a predicted signature of the Big Bang. Once this radiation source was identified, it has been extensively analyzed by satellite probes. The data these satellites have generated have been described as "the Holy Grail of cosmology" and, as far as the scientific community was concerned, the death knell of the 'steady state' theory. (Davies, 1996)

Bondi and Gold quietly acquiesced to this turn of events, but Hoyle and a handful of colleagues kept their model on something like 'life support' by continually modifying the theory, in the manner of Ptolemy's epicycles. The patient was dead, but someone had forgot to ask Fred to sign the 'do not resuscitate' form. The brilliant theorist who had dominated British astronomy in the 1950's became, bit by bit, something of an embarrassment by the end of the 1960's. When Sir Fred's request for a new computer was denied in 1972, he abruptly resigned from his post with great bitterness and for the rest of his career divided time between his home in the Lake District and a series of temporary posts in academia. (O'Connor and Robertson, 2006). His intellect was undiminished, but also adrift, and he seemed at times to court controversy simply because it was expected of him. As he jested about himself, "When I was young, the old regarded me as an outrageous young fellow, and now that I'm old, the young regard me as an outrageous old fellow." (Gregory, 2005)

The scope of this paper does not permit a detailed treatment of all the fringe ideas that Hoyle entertained in his long semi-retirement. They were many and varied, and some of them have gained a measure of respectability after his death. Hoyle remained suspicious of biological evolution's ability to account for life's origins, and was much-criticized for pushing his hypothesis of 'panspermia', in which Earth was 'seeded' with life from other worlds. But the greatest shock to many of his colleagues in astronomy was Fred's deconversion from atheism. While never a conventional believer, his encounter with the triple-alpha process had a surprising aftermath.

Hoyle revisited his experimental result of 7.656 MeV more than once, aware that the resonance is based on an interaction between the strong nuclear force and the electromagnetic force. To his surprise, Hoyle found that if you changed the strength of the strong force by as little as one percent, then the resonance that makes life possible would not exist. Hoyle had effectively reasoned, life must exist, therefore the resonance level must be there. But, to his shock, that conclusion also meant that two parameters of the present Universe must be improbably “fine-tuned” for life. (Davies, 2006)

Notice that Hoyle’s line of reasoning here threatens to overturn previous notions from Copernicus and others about the mediocrity of the human position. In order for living things to exist, they must be fact be part of a set of outcomes which are privileged by the initial parameters. Eventually, another astronomer by the name of Brandon Carter formalized Hoyle’s assumption as yet another Principle for astronomers to chew on. This so-called **Anthropic Principle** does not, as the name suggests, point exclusively to human beings as being privileged, merely to carbon-based life of some sort, but the name has stuck.

To make matters worse, the term “Anthropic Principle” has a well-accepted usage in science, but a more speculative usage in the popular culture, and this has ironic and confusing consequences. In effect, there is a ‘weak’ version and a ‘strong’ version that differ in terms of what is claimed, and Hoyle, true to form, moved rather quickly from the ‘weak’ version that no one cared to argue, to a ‘strong’ version that fairly reeks of sulphur and brimstone. (Barrow, 2002)

Keeping in mind that Hoyle was a Yorkshireman, blunt and independent to a fault, keeping in mind that Hoyle was an atheist, with an aesthetic preference for a static, eternal Universe, rather than one that was user-friendly for theists like Pius XII, keeping in mind that was he animated by a conviction and long habit to go against the crowd, his conclusion is remarkable. In a oft-quoted passage, he wrote:

*“Would you not say to yourself, “Some super-calculating intellect must have designed the properties of the carbon atom, otherwise the chance of my finding such an atom through the blind forces of nature would be utterly minuscule.” Of course you would . . . A common sense interpretation of the facts suggests that a superintellect has monkeyed with physics, as well as with chemistry and biology, and that there are no blind forces worth speaking about in nature.”*

Lest anyone think that Hoyle has unduly reified an isolated finding, it should be pointed out that there are quite a few other cases like this in astronomy. As **Paul Davies** (1992) has written, “If we could play God, and select values for these natural quantities at whim by twiddling a set of knobs, we would find that almost all the knob settings would render the universe uninhabitable. Some knobs would have to be fine-tuned to enormous precision if life is to flourish in the universe.”

A surprising number of astronomers, if not cosmologists, have quietly come to a conclusion similar to Arno Penzias, co-discoverer of the background radiation: "The best data we have are exactly what I would have predicted, had I had nothing to go on but the five books of Moses, the Psalms, the Bible as a whole." (Davies, 1992)

This strong version of the Anthropic Principle continues to lurk in the background of cosmology, but remains problematic. Richard Dickerson has said that, "Science, fundamentally, is a game with one overriding and defining rule:

Rule No. 1: Let us see how far and to what extent we can explain the behavior of the physical and material universe in terms of purely physical and material causes, without invoking the supernatural." (Dickerson, 1992)

It is not clear how scientists can pursue what is essentially an inference of design in the cosmos without stepping outside this game of science, and risk becoming something of an outlier like Hoyle, whose rhetorical excesses and fringe interests probably cost him a share of the 1983 Nobel Prize. It is a pity, because science needs more leaders who are willing to not only tackle the big questions, but to be (as Hoyle often was), gloriously, spectacularly wrong.

I close with a passage from speaks volumes about Hoyle's personality and how he approached the business of science. It is by turns ironic, pathetic yet heroic:

*"But the question then is: can it (obstinacy) interfere with one's judgement? Well, let me make it absolutely clear that obstinacy is only of value in so far as it allows you to discount the opinions of other humans. The sense of obstinacy that goes against the facts is deadly. It is terrible, and you must not have that at all."*

*"You see, the real thing in science is not the talking among the humans, the real confrontation is between the human brain and the universe. And once a person becomes controlled by their relation to other humans, then they lose that essential connection, and that's really what I mean by obstinacy. For myself the satisfaction comes when out of the brain I've managed to deduce that such-and-such should happen. Then, what I do is actually go away and take a look; and if I find it is so, I have a feeling that I've scored a point over the universe." (Gregory, 2005)*

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