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Numerology and the Cosmos: Alternative Cosmologies in 1930s Britain

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1.

The 1930s saw a quiet rebellion develop in the growing field of physical cosmology. This rebellion saw its most ardent and persistent warriors plying their trade in Great Britain. The precise date for the beginning of this rebellion could probably be given as the day in 1928 when Sir Arthur Eddington first read Paul Dirac's famous paper describing the wave equation for an electron. With that in mind, a little background on physical cosmology is called for in order to lay the groundwork for our look at the 1930s rebellion.

Cosmology, being the scientific study of the origins and structure of the universe on a large scale, has been discussed since the dawn of man. In fact, it can be said that anyone who stares at the sky and our surroundings here on Earth and simply wonders why and how it all came about, is a cosmologist to some extent.

Prior to the Renaissance, philosophy, theology, and science were intimately linked. Slowly, however, throughout the past 400 years or so these intimately related fields have diverged. Science has become more analytical while philosophy has become more metaphysical. This has left cosmology in a rather troubled position. The questions cosmology seeks to answer are most definitely metaphysical and cosmical in nature. They have a very profound impact on religion and philosophy. But today's methods for truly understanding cosmology are almost purely analytic - and wholly successful. Which is not to say there is no place for philosophy. Philosophy and theology, or religion, give meaning to the scientific results for many people.

Frequently, scientists attempt to play the role of not only scientist but also of philosopher. Sometimes this can lead scientists to change their method of research and can color the results. Again, this is not always bad, and, in fact, it could be argued that no scientist is free from personal bias, but occasionally this can lead a scientist far away from the mainstream. This, in fact, is a commonality between science and art. Unlike engineering where the 'correctness' or 'weight' of one's results are immediate - either an invention or creation works or it doesn't - science and art can take centuries to be truly understood and appreciated. Thus being led away from the mainstream also does not always mean a theory or observation is incorrect. In an effort to better understand such theories and observations, historians must continually reanalyze them in order to assess their impact on existing science and, perhaps, discover that long lost gem buried in a previously incomprehensible theory. However, more often than not, very little of true scientific merit is found and most theories like this are only interesting from a historical viewpoint.

Theories that generally are now considered to fall into the latter category were developed in cosmology in the 1930s by three cosmologists in Britain. The beginning of the 20th century brought about the advent of relativity theory which forever changed the study of physical cosmology for it removed the idea that the universe was static and unchanging. It in fact eventually predicted that it was expanding which led scientists to produce the theory of the Big Bang, which, incidentally was a derogatory term given to it much later by Sir Fred Hoyle whose own steady state theory was reportedly developed as a rebuttal to the Pope's endorsement of Big Bang cosmology as being in line with Catholic theology. This is a case where personal bias seems to have spawned a complete theory which is still be investigated today a half-century after its initial development.

Around the same time that relativity was first appearing on the international physics scene, another small revolution was taking place in the physics community. Not long after relativity was first introduced the new quantum theory began its development having been born out of Max Planck's early investigations. From the very beginning of these two theories researchers have attempted to merge them into a single, concise theory, something which has yet to be done satisfactorily. [Some think string theory holds the final clues, but the problem is that string theory is untestable at the present time].

As quantum theory developed theorists began applying it to different situations. Early 20th century experiments showed that certain subatomic particles seemed the behave as if they had an intrinsic angular momentum or spin. Quantum theory initially had trouble describing particles that had spin. However, in 1928 a young British theorist named Paul Dirac produced an equation that successfully described particles with a single unit of spin (in particular electrons). This revolutionary discovery was, in fact, the pivotal moment in the birth of a new cosmological movement and the movement's founder was another British theorist named Arthur Eddington.

2.

By 1928 Sir Arthur Eddington had established himself as one of the preeminent physicists of the new century having contributed a great deal of original work to astrophysics and mathematics. To this day Eddington's name resounds in the world of astrophysics in such named quantities as the Eddington luminosity and the Eddington limit. Eddington was a strong supporter of Einstein's relativity theory and felt that tensor calculus, which is the form of mathematics used to describe relativity, was destined to become the mathematical cornerstone of future research in physics. That is why Dirac's 1928 paper disturbed him greatly.

Dirac was a complete newcomer to quantum theory only a few years before until Sir Ralph Fowler at Cambridge introduced it to him and introduced him, via Niels Bohr, to Werner Heisenberg, one of quantum theory's leading proponents. Dirac's approach was one of fairly standard method in quantum theory and thus when he extended the theory to include electrons in 1928 he merely extended the method as well. This meant that his description for electrons in quantum theory, which was a relativistic situation, did not appear in tensor calculus. This is what disturbed Eddington. He felt that any relativistic equation ought to be written in tensor calculus as relativity itself was written in such a form.

Eddington felt the time had come to develop a comprehensive theory including both relativity and quantum theory in an attempt to ultimately determine the structure of everything. Examples of the types of structure Eddington sought to deduce from such a unified theory included the ratios of the masses of the electron and proton and the fine structure constant which held the key at that time to the spectral characteristics of the hydrogen atom.

Eddington began his quixotic quest in December of 1928 when he asserted that the fine structure constant was the reciprocal of a whole number. In February of 1930 he claimed that whole number to be exactly 137 (it is in fact not a whole number but actually). Simultaneously he set out to devise a 'wave-tensor' form of calculus that would properly encapsulate both relativity and quantum theory and better represent such items as the Dirac equation. In order to do this Eddington was required to find a common meeting point of relativity and quantum theory. He found this in the state of equilibrium of a radiationless, self-contained system of a very large number of particles. A molar relativistic solution to this state was found earlier by Einstein.

In relativity this problem consists of thinking of the large number of particles as all exerting gravitation and, thereby, producing curvature on the space-time surrounding them. So if the particles are the constituents of the universe then the space-time of the universe is curved. Thus the universe is closed and has a radius of R. This is called an Einstein universe.

In quantum theory an analogous situation can be found in the ground state of a radiationless steady-state system - so for instance a group of non-radiating particles all in their ground state (which is their state of lowest energy). One then needs to find a solution for this that also satisfies the conditions for an Einstein universe, as described before, that has zero pressure and temperature.

The solution to the relativistic problem will be in term of G, the gravitational constant, and Ω, the cosmological constant. The quantum mechanical solution will be in terms of h, which is Planck's constant, and other microscopic constants. If the two solutions are expected to agree with one another - i.e. describe the same thing - then a comparison of the results would produce a ratio of the constants (G, h, etc.).

Through a number of laborious calculations Eddington was able to make both solutions lead to the number N which he termed the 'cosmical number', not to be confused with the cosmological constant previously mentioned. This cosmical number was:

$$N = \frac{3}{2} \cdot 136 \cdot 2^{256}$$

which is roughly equal to 10^{79} - the number of particles in the universe (in fact, this number is still considered to be the number of particles in the universe). Eddington's cosmical number appears quite often in his calculations. One very interesting application of his number was in calculating the ratio of the electric force to the gravitational force between an electron and a proton. The electric force between an electron and a proton is:

$$F_e = k\frac{e^2}{r^2}$$

while the gravitational force between an electron and a proton is:

$$F_e = G\frac{mM}{r^2}.$$

Eddington played with the electric force a bit and dropped the $1/4\epsilon^2$ portion of k, keeping only the $1/\pi$. The ratio of the two forces then works out to be:

$$\frac{\pi e^2}{GmM} = (3N)^{1/2}$$

Eddington employed a number of other computational techniques to derive such things as the masses of the electrons and protons. Through this thought experiment he attempted to demonstrate that gravity was a direct consequence of the exclusion principle which means, in lay terms, that gravity was a consequence of quantum mechanics.

While Eddington's conclusions were certainly revolutionary, his methods were unheard of. To some, it appeared as if he simply played with number combinations until he found the solution he was seeking. To Eddington he was deliberately employing philosophical reasoning in attempting to derive a theory that not only combined relativity and quantum theory, but that also wove science together with philosophy and mysticism. Eddington referenced the work of Johannes Kepler who is known, historically, as one of the most influential astronomers ever, but who was also a known mystic. Eddington specifically referenced Kepler's mystical work. He also deliberately referenced the work of Pythagoras who was a known mystic. Not much is known about Pythagoras or his followers, the Pythagoreans, but it is possible that they followed the lead of other Greek philosophers in employing deductive reasoning. This meant that observations, though important, were secondary to rational reasoning. Eddington used rational and deductive reasoning almost exclusively. It was his opinion that all the laws of physics could simply be deduced from logic and observation would follow.

This same style of thinking was employed by Edward A. Milne, another of Britain's foremost mathematical physicists of the early 20th century. Milne was perhaps not as well known publicly as Eddington, but was certainly an equal intellectually. Unlike Eddington, however, he was not interested in uniting relativity and quantum mechanics. Milne's initial motivation for his work arose out of his dissatisfaction with Einstein's general relativity. Milne found relativity to be too obtuse and sought to find a more accessible theory.

To Milne the idea that space had structure to it was absurd. He felt that space was simply a reference system. As such he did not rely on gravitational or dynamic assumptions. In fact his theory was based merely on two basic postulates. The first postulate was that the speed of light was a constant and a maximum. The second postulate was what we now know as the 'cosmological principle' - that the universe is isotropic and homogenous on a large scale. In fact it was Milne who first coined the term 'cosmological principle.' With these two principles and without general relativity he was able to derive a uniformly expanding world model.

Milne's model had three major consequences to it. The first was that the gravitational constant, G, was not a constant after all, but instead grew slowly with time. However, he didn't believe that this result was, in fact, testable and thus was forced to include some type of correction for this fact. What he developed was a system of two separate time scales - kinematic time, t, and Newtonian (dynamical) time, τ. The two time scales were related by the following relation:

$$\tau = log\left(\frac{t}{t_0}\right) + t_0$$

where t_0 is the present epoch. Thus, for us, t is always equal to t_0 and G was reduced to a constant. A plot of this relationship can be seen in Figure 1.

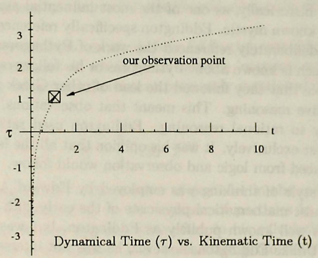

Figure 1

The dual time scales also resulted in a stationary universe with an infinite past age. This, of course, was a precursor to the present steady-state theory of cosmology as developed by Sir Fred Hoyle. This also meant that there were an infinite number of particles in the universe, a result also deemed untestable by Milne, and meant that there were essentially two versions of "reality" each following a different time scale. This led Milne to state that questions about "reality" were scientifically illegitimate.

The second consequence to Milne's world model was that it was the first time the Hubble law of recession (the relationship between redshift and distance) was shown to be trivial. He began his proof through a simple thought experiment. He assumed that there exists a number of non-interacting particles in flat space. If they suddenly undergo an explosion, a wide range of velocities are produced among the particles with an isotropic distribution. The fastest of these particles will, naturally, move farthest away (simply because they're quicker). Therefore the velocity each particle will have is equal to the distance from the explosion divided by the time since the explosion. If the universe is homogenous and the proper distance between neighboring comoving observers increases, then a vector addition of the velocities results in Hubble's law.

Milne went on the perform work on the Friedmann-Lemaitre model for expansion. Working with Sir William McCrea he was able to show that this model could be derived using elements of Newtonian mechanics. Basically Milne's cosmology uses what is called a Minkowski metric which basically means the universe is flat. Under the cosmological principle, an observer can be assigned fixed spatial coordinates (in polar coordinates this means r, θ, and φ). The metric that can be derived from this, when compared with the Robertson-Walker metric (which is generally used in Big Bang cosmology) shows that Milne's metric does not have singularity - which means there was no Big Bang in Milne's model. Thus, basically, Milne just provided a labeled reference frame for flat spacetime.

Now Milne had a problem with the standard relativistic treatment of cosmology because it included a particle horizon. In basic terms, this problem boils down to: if two galaxies (particles) have not been in causal contact with each other since the singularity, how would they look similar? In modern cosmology this problem has been solved by inflationary models. However, inflation did not exist until the late 1970's and early 1980's. Therefore, at the time, Milne considered this to be one major argument against the relativistic theories.

Melding certain aspects of the theories of Milne and Eddington together, Paul Dirac embarked on his quest for a comprehensive cosmological model in 1937. His model, like Eddington's, contained a large amount of number theory and "numerology." In fact the theory was eventually called the Large Numbers Hypothesis (LNH). Dirac felt that all large dimensionless constants were interconnected and functions of the age of the universe (i.e. time). He found himself mostly focusing on numbers of order of magnitude 10^{39} and 10^{78}. His reason for focusing on the former was that, if he assumed that there existed a unit of time given by e^2/mc^3, then the age of the universe, which he assumed, incorrectly, was 2 billion years, would be predicted to be 10^{39}. This number is also very nearly the same as the ratio of the electrostatic force and gravitational forces between an electron and a proton. We derived this result in our discussion of Eddington's work and, indeed, this is true. The final relation Dirac derived was:

$$\frac{T}{(e^2/mc^3)} \approx \frac{e^2}{GmM}$$

where T is the Hubble time ($1/H$). The odd consequence of this relation is that if the numerical agreement is significant between the two sides of the equation and the values for fundamental charge and the masses of the particles do not change, then the only way that this can hold universally is if G, the gravitational constant, decreases with increasing time! Thus, as Milne had an increasing value for G, Dirac has a decreasing value.

In a later paper criticizing this reasoning, Teller argued that a decreasing G would make the age of the Sun too young when compared with actual evidence. Dirac countered this with two potential solutions. His first solution was that dust accretion increased the Sun's mass on a regular basis thereby throwing off the age calculations, or that there exist two time scales, similar to Milne's idea, where one is atomic and the other is global (Newtonian). Dirac chose the double timescale approach as it also seemed to explain a discrepancy in the Moon's age where the age determined by orbital analysis versus that obtained by radioactive dating of moon rocks did not match. Dirac argued that the atomic time would explain the radioactive decay while the global time would explain the orbital analysis. Other related results also showed that Dirac's theory correctly predicted (in line with observation) the inward spiral of planetary orbits.

Philosophically, Dirac agreed with Eddington that large dimensionless numbers were of great importance. He felt that they depended on the history of the universe and therefore on cosmic expansion. He went on to extrapolate several dimensionless numbers related the Hubble time to mean density of matter and other values to reproduce Eddington's cosmic number, 10^{78}. This, of course, is also the square of the period in atomic time, 10^{39}. The result is that the number of particles will increase with time! This means that there is continuous matter creation in Dirac's universe! This is a curious result that pops up again in the modern steady state theories developed by Sir Fred Hoyle, Geoffrey Burbidge, Jayant Narlikar, and others. However, in 1938, Dirac reversed his stance and declared that matter was conserved in his universe. But the seed had already been planted, it seems, and the idea lived on for a few more decades.

One of Dirac's most curious results from his theory was that because the value $e^2/\hbar c$ is dimensionless, it should be derivable from general principles. Thus only e or $\hbar$ can be fundamental. If it is $\hbar$ then e is derived and contains a square root which is unlikely. Therefore, $\hbar$ must be derived which would mean the entire view of the uncertainty principle would need to be altered!

Another interesting result of his theory was that it predicted the cosmic microwave background radiation. Basically, a slower decrease of temperature with time meant the radiant temperature extrapolates back to $m_p c^2/k$ at the origin, obviating the need for matter/radiation decoupling in the early universe.

3.

So we have seen three very unorthodox theories developed by three, seemingly, orthodox men. What possessed them to develop these radical concepts? What drove them to think in such a way that it defied observation in many cases? How is it that they all developed their ideas around the same period in the same country? There is, for certain, no simple answer. But there certainly are common threads that can perhaps give a glimpse into the minds of these brilliant, though perhaps a bit misguided, men.

On a personal note, one thing all three had in common was an acquaintance with Sir Ralph Fowler. It is indeed Fowler exerted some influence, knowingly or unknowingly, over all three. He certainly had an affect on Milne and was a major catalyst in Dirac's life. It was Fowler who introduced Dirac to quantum theory, Dirac having been nearly ignorant of the burgeoning subject before arriving at Cambridge to work with Fowler. It was also Fowler who introduced Dirac, via Niels Bohr, to Werner Heisenberg. And, as we have seen, it was Dirac's 1928 paper on the relativistic nature of the electron that touched off this entire debate.

Fowler was certainly a brilliant physicist. However it was for his depth of influence and charisma for which he is probably most known. Between 1922 and 1939 Fowler supervised at Cambridge 15 future Fellows of the Royal Society and 3 future Nobel laureates. In total during this period he supervised no less than 64 students giving him an average of 11 at one time. This might lead on to believe that he did not have any depth of relationship with any one person. As with Milne this could not be further from the truth. Milne, in particular, was wholly affected by him calling him a "prince among men." Milne and Fowler's relationship dated from their days together in the Ordnance Office in Word War I, but continued on to Cambridge where Fowler was mentor and friend to the young Milne. Ironically Milne outlived his mentor by less than a decade.

Fowler was a product of the late Victorian education system in Britain. Indeed the Victorian age proved to be quite instrumental in his young life. Victorian thought, in fact, had a lasting impact on British society in general and directly impacted Milne, Eddington, and Dirac, as well both directly in their youth and indirectly through lasting imprints on their mentors and society in general.

Two aspects of Victorianism had direct influence on the works of Eddington, Milne, and Dirac. The first was a strict social system that was quite nearly caste-like in its nature and that was tremendously religious. The second was a mystical fascination with the unknown. Focusing initially on the first, we note that religion was very important in Victorian English society. There was quite a bit of religion and this era saw the dawn of a number of religious cults and zealots. Early in the Victorian age much of the religious fervor was traditional.

In the early 19^{th} century when deductive logic was being championed at schools on the continent, many argued fervently that it not be introduced to the more ecclesiastical Cambridge and Oxford (no one objected to its use at the secular University of London, however). One of these religious champions of William Whewell. Whewell argued in *Astronomy & General Physics* that inductive science was experimental and more supportive of religion than deductive science. He most often cited Newton and Kepler as examples. It should be noted that, in an ironic twist, Eddington deliberately referenced Kepler in his *Fundamental Theory* whilst also using a purely deductive form of reasoning.

Whewell's work was one of the earliest differentiations of the two types of reasoning. To Whewell deductive reasoning was too mechanistic and didn't have enough room for physics. And in fact the chief proponents of deductivism on the continent were mathematicians such as D'Lambert, Clairault, Euler, Lagrange, and Laplace (note the French origin of Whewell's deductivists).

Why was Whewell against deductivism? He felt that it gave insights that were normally limited to religion. Richards attests that "a religion that rested on evidence attested to by personal experience and conviction had no standing in probabilistic discourse" which was a deductive and mechanistic science and was precisely the science Whewell was trying to keep out of Cambridge and Oxford. But wasn't, in fact, Christianity based entirely on faith which is, in Whewell's definition, purely deductive as it has little physical evidence to support it - and indeed does not even call on it? Milne appeared to think so and, in any case, Charles Babbage countered Whewell by creating a deductivist argument for God by saying that miracles has a physical explanation we didn't understand.

In fact, Milne's deductivist arguments led to developing cosmophysics into a supporting theory for Christianity. In an ironic twist Milne's cosmophysics eventually served as a basis for Sir Fred Hoyle's steady state theory which, legend has it, Hoyle developed in response to the Pope's glowing endorsement of Big Bang cosmology.

Whewell later developed a new version of his inductivism that, in reality, was more like Milne and Eddington's deductivism. The common thread was that theories were not derived from observations but rather a theory resulted when an investigator identified a 'fundamental idea' that explained an observation. Whewell's fundamental ideas were wholly human and generated by a purely deductive process of conceptualization which is, in fact, just like Milne's process whereby to know the truth of a matter meant thinking properly about it. This was very different from the continental deductivism of the early Victorian age which was largely calculative in nature.

James D. Forbes responded to Whewell by stating that knowledge was grounded in personal insight and that true understanding was just beyond rational constructions which meant that every discovery ultimately produced another question.

Questions were ultimately a fundamental bedrock of Victorian society, though not overtly so. The Victorian age, while in one sense strict and unquestioning in its social structure, pushed the bounds of exploration and attainment of knowledge. This was the age of Darwin, Livingstone, Scott, and Maxwell. With this ability to question the ultimate nature of life came a fascination with stories that expanded those traditional boundaries, particularly in the late Victorian age. This was the birth of science fiction and the age of gurus and charm peddlers.

H.G. Wells, one of the founders of science fiction who began writing in the 1890s, pointed out that the major change during the Victorian age was that the worldview became much more cosmic in nature, though still mystical, with new views of time, space and evolution. Wells himself touched on these topics in such well-known books as *The Time Machine, First Men in the Moon, and The Island of Dr. Moreau.*

Science fiction was truly born in serials such as *The Strand* and *Pearson's Weekly* in the 1890s when publishing machinery had caught up with existing needs. It became much less expensive to mass-produce the written word. This was when 'Martianism' was born in stunning detail as science and science fiction seemed to feed off of each other.

Returning briefly to the discussion of William Whewell, his piece *Astronomy & General Physics* was the first of the Bridgewater Treatises which were entirely secular works. Frayter called Wells' *Island of Dr. Moreau* an anti-Bridgewater Treatise where the beneficent God was replaced by a vivisectionist. Charles Darwin's cousin Frances Galton, around the same time, developed his theory of eugenics which was displayed in a dark and alien way in Wells' *First Men in the Moon.* The interesting aside to this is that Darwin's son Horace worked closely with Sir Ralph Fowler as well as Milne and Eddington, and Charles Galton Darwin, another of the Darwin family, was the person whom originally communicated Milne's original paper on cosmophysics at a conference.

In the late Victorian age the concept of entropy, developed from the rapidly expanding field of thermodynamics, became a physical and social metaphor. Additional theories that straddled the border of fiction and reality included the newly revised concepts of time and space. Wells once again rose to the occasion in *The Time Machine* displaying time as traversable in more than one direction, essentially presenting it as a dimension.

This scientific theory really began with Riemann's work with non-Euclidean geometry and his development of hypersurfaces in 1854. To explain his hypersurfaces he invented fictional creatures called flatlanders who could only live in two dimensions but who experienced the third dimension as a sort of force. This concept was introduced to England in 1884 when Dr. Edwin Abbott, a New Testament scholar, published the hierarchical novel *Flatland* in which flatlanders were but one of many dimensionally limited species.

Further work in hypersurfaces helped build the basis of Einstein's relativity and, thus, played an important role in the development of Eddington, Milne, and Dirac's theories. Some of this work was taken up by the young Charles Hinton. Hinton's father was a famed bigamist in England and Charles took up the family tradition taking the daughter of George Boole (of Boolean algebra fame) as his first wife. He fled to the United States where he subsequently invented the automatic pitching machine for the Princeton University baseball team before spending two years at the U.S. Naval Observatory and then his final years at the U.S. Patent Office where, in 1907, he dropped dead at a reception in the middle of a toast to female philosophers. Hinton implied in his writings that the diety resided in the fourth dimension and that it explained ghosts and miracles. He also developed teseracts which are a curious mathematical way of projecting four dimensions onto a two-dimensional surface.

All of these oddities combined with the religious zeal and social structure of the Victorian age, colored Britain for some time to come - and, indeed, they color Britain today. But these Victorian ideas were still pervading society when the young Eddington, Milne, and Dirac took up their quests for the ultimate theory. It is not perhaps too wide a suggestion that they were affected by these ideas, even directly.

But one does not need to conjecture that Pythagoreanism affected Eddington - he stated as much in describing his motives for the development of his 'fundamental theory'. In addition, Eddington and Milne used deductivism almost exclusively in their cosmological theories, which was the chief method of Aristotle, another ancient scholar.

Pythagorean mathematics was based largely on deriving new knowledge from whole numbers. For example, the famous Pythagorean Theorum involves the combination of whole numbers in such a way as to produce a triangle. Robinson say that after the Pythagorean discovery of musical intervals, it was realized that Pythagoras' genius lay in the ability (and possibility) that all order could be understood in terms of a number. This was first hinted at by Anaximander, but it was Pythagoras established the mathematical order of nature. The Pythagoreans, according to Aristotle, brought "heaven into being" out of numbers. Thus, to the Pythagoreans, if everything is a number, then the generation of a world-order meant the generation of a number! This is precisely what Eddington and Dirac proposed in their respective theories!

The Pythagoreans also had a mystical side that ties in a bit with the late Victorian age. Not much is known about this aspect of them, but it is known that they were a secretive group and were quite nearly a cult. It is not even clear how much of Pythagoras' work was his own and how much can be attributed to his followers.

Thus we have witnessed the development of three highly unusual cosmological theories, all developed in the 1930s in Great Britain by eminent scholars who, otherwise, produced lasting and groundbreaking work. What influenced these men to leave the mainstream and delve into alternative viewpoints? I have suggested three potential sources of influence, both conscious and subconscious. Were there more? Most definitely there were. But these three - Fowler, Victorianism, and Pythagoreanism - are a starting point for explorations into the true nature of the motivations of these great thinkers.

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