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# Cosmology and the Origins of Life

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New evidence related to the origins of life in the cosmos combined with continuing progress in probing conditions of the early universe using the James Web Telescope suggest that long-held orthodox positions may be flawed. Only by objective evaluating the new facts and recognising the cultural forces at work can further progress be made towards resolving perhaps the most important and fundamental questions in science.

**Keywords:** Panspermia, interstellar dust, comets, cosmology

## Introduction

In the modern technologically-driven world in which we live we tend to forget the cultural backdrop against which key scientific concepts are being rigidly maintained. These considerations do not apply however to well-established theories such as planetary dynamics and quantum physics, for example, that are rigorously based on prediction, experiment and verification. They apply to the much grander visions of cosmology and biology that lead to the boldest of assertions on how the universe and life within it arose. We shall point out that these latter pronouncements are by no means as secure as we are all too often made to believe.

The enlightenment in Europe in the 17th century heralded the beginning of the scientific method as well as the birth of scientific academies in Europe whose mission it was to put science on a firm rational and empirical basis. These developments served to stem the growth of superstition, magic and witchcraft that were rampant at the time. The advancement of empirical science that followed served us well for several centuries thereafter. However, over time, such benefits and advances began to act in a negative way by encouraging the rigid defence of scientific orthodoxies often against a tide of contrary evidence. Current attitudes to the origin of the universe as well as biology within it – the Big Bang theory and the theory of spontaneous generation of life on Earth - arguably fall into this latter category. Indeed, the ongoing insistence on defending scientific orthodoxies on these matters, even against a formidable tide of contrary evidence, has turned out to be no less repressive than the discarded superstitions in earlier times. For instance, although all attempts to demonstrate spontaneous generation in the laboratory have led to failure for over half a century, strident assertions of its necessary operation against the most incredible odds continue to dominate the literature (6).

Modern scientific ideas relating to the origin of life and the origin of the universe are directly traceable to Eurocentric philosophies that had developed mainly in the timespan between Aristotle (3rd century BCE) and St Thomas Aquinas (1225-1272CE). It should come as no surprise that St Thomas Aquinas accepted the entire Aristotlean corpus in so far as it related to Christian theology. The clashes with astronomical observations challenging geocentric cosmologies involving Galileo, Copernicus and Geodarno Bruno are of course well known. Perhaps less well known is the acceptance of the Aristotlean idea of the spontaneous generation of life – *fireflies emerging from mixtures of warm Earth and morning dew* – which forms the cornerstone of biology and persists in a modern form under the name of "abiogenesis".

Aristotle's idea of spontaneous generation of life posed a direct challenge to an earlier idea – panspermia – attributed to the pre-Socratic Greek philosopher Anaxoragas of Clazomenae who lived around 500BCE. Panspermia implies that the "seeds of life" are eternally present in the cosmos and takes root whenever and wherever the condition permit. Closely similar ideas prevailed in ancient India many centuries earlier for instance in the Vedas positing life to be an integral part of the structure of the universe.

**Pasteur and life in the cosmos**

The first serious attempts to re-examine spontaneous generation and to investigate panspermia from an experimental standpoint began with the French biologist Louis Pasteur in the early 1860's (1). Pasteur showed by means of laboratory experiments that what was already known for larger visible life forms - that life is always derived from pre-existing life of a similar kind. This casual chain of events – life from life - is true not only for life forms existing today but it is also true throughout the record of fossilised life on the Earth. The question that next arose already in the early 20th century is: when and where this connection cease to operate. We are then forced logically to conclude that the chain of "panspermic" connection continues "for ever" which in turn demands a cosmology that must also continue "for ever" in some form.

This connection has been discussed by several contemporary physicists. For instance, the German physicist Hermann von Helmholtz (2) wrote:

"It appears to me to be fully correct scientific procedure, if all our attempts fail to cause the production of organisms from non-living matter, to raise the question whether life has ever arisen, whether it is not as old as matter itself, and whether seeds have not been carried from one planet to another and developed everywhere where they have fallen on fertile soil…"

And in Britain Lord Kelvin (William Thomson) at about the same time declared "Dead matter cannot become living without coming under the influence of matter previously alive. This seems to me as sure a teaching of science as the law of gravitation……" (Ref.3)

Despite these enlightened responses that was followed by the championing of panspermia by Svante Arrhenius (4), a rigid orthodoxy advocating spontaneous generation prevailed well into the 20$^{th}$ century.

**Problems with Spontaneous Generation**

Fred Hoyle and one of us were perhaps the first to revive a serious interest in challenging spontaneous generation bringing forward a new case for panspermia. The first criticism of spontaneous generation that was voiced in the early 1980's (4,5) related to issues of probability of assembly of the crucial monomers of biology into a primitive living system. This was necessary to discuss because the chemical building blocks of life were being discovered to exist in vast quantity throughout the universe. The analogy that was made to a tornado blowing through a junk yard assembling an air plane is just one metaphor that came to be deployed to drive home the improbability of the transition from life molecules (monomers) to the simplest replicable lifeform.

Over the past few decades biologists have further unravelled the mind-blowing complexity of life at the molecular level and consequently laid bare its super-astronomical information content. Such a complexity is manifest for instance in the arrangements of amino acids in crucial enzymes, or nucleobases in DNA. The precise "information" contained in enzymes—the arrangements of amino acids into folded chains—is transmitted by way of the coded ordering of the four nucleotide bases (A,T,G,C) in DNA. In a hypothetical RNA world, that some biologists think may have predated the DNA-protein world, RNA is posited to serve a dual role as both enzyme and transmitter of genetic information. If a few such ribozymes are regarded as precursors to all life, one could attempt to make an estimate of the probability of the assembly of a simple ribozyme composed of 300 bases. This probability turns out to be 1 in $4^{300}$, which is equivalent to 1 in $10^{180}$, which can hardly be supposed to happen even once in the entire 13.9-billion-year history of the canonical Big Bang universe. And this is just for a single enzyme. In the simplest known bacterium *M. genitalium* with some 500 genes coding for enzymes the improbability escalates to a super-astronomical scale (6,7).

**Geological and astrophysical evidence**

Four decades ago the earliest evidence for microbial life in the geological record was thought to be in the form of cyanobacteria-like fossils dating back to 3.5 Ga ago. From the time of formation of a stable crust on the Earth 4.3 Ga ago following an episode of violent impacts with comets (the Hadean Epoch) there seemed to be available an 800 million years timespan during which the canonical Haldane-Oparin primordial soup and the spontaneous generation of life may have arguably developed. Very recent discoveries, however, have shown that this time interval has been effectively closed. Ancient rocks laid down 4.2 billion years ago belonging to a geological outcrop in the Jack Hills region of Western Australia have been found to contain micron-sized graphite spheres with an isotopic signature of biogenic carbon – fossil bacteria at a time when the collisions of the Earth with comets and asteroids were happening at a relentless pace (8). The requirement now, on the basis of orthodox thinking, is that an essentially instantaneous transformation of non-living organic matter to bacterial life took place, a proposition that strains credibility of Earthbound abiogenesis to its utmost limit as we have already noted. A far more plausible proposition, in the light of the new evidence, is that fully-developed microorganisms arrived at the Earth via impacting comets, and these became carbonized and trapped within ancient rocks.

The crucial step from non-living organic molecules to primitive life-forms – bacteria and viruses – that can carry the entire range of possibilities for evolution of life could not, however, have happened on the Earth, on the surface of any planet, comet or asteroid nor indeed on any other restricted astrophysical setting. The evidence, in our view, points to such a transformation being linked to cosmology on the largest possible scale.

Since the early 1980's astronomical evidence has steadily accumulated that point inexorably to interstellar dust having a distinct biological provenance (4,5,9,10). Spectral features spanning the spectrum from the mid-infrared, visual and ultraviolet wavelengths have shown consistency with biological material in various states of degradation. A selection of the key astronomical data is displayed in Fig. 1 – points representing the data, and the curves the theoretical fits based on the omnipresence of bacteria, viruses, and their degradation products.

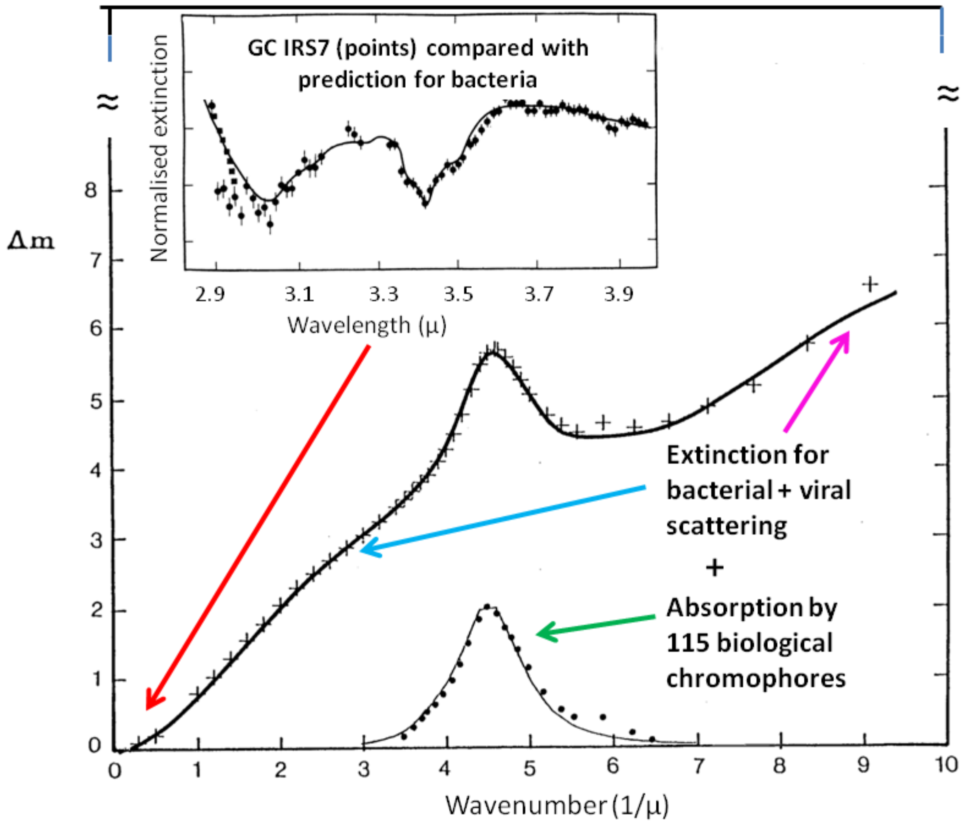


Fig. 1. *Upper Curve Main frame* The mean extinction curve of the galaxy (points) compared with the contribution of desiccated bacteria and nanobacteria.
*Lower curve Main frame* The residual extinction (points) compared with the normalized absorption coefficient of an ensemble of 115 biological aromatic molecules.
*Inset:* The first detailed observations of the Galactic centre infrared source GC-IRS7 (Allen & Wickramasinghe 1981) compared with earlier laboratory spectral data for dehydrated bacteria. (See citations in refs 9,10)

The first strong hint of a biological connection emerged in the absorption spectrum of galactic dust over a 10kpc pathlength from the Galactic Centre source GC-IRS7 shown in the inset of Fig.1. An absorption profile in the 2.9-4 micrometre wavelength range that was *predicted* for a bacterial component of interstellar dust was found to be present in the interstellar when the first observations (points in the inset) were subsequently made. The main panel shows a broad ultraviolet absorption feature of interstellar dust centred on the wavelength 2175A that was attributed to aromatic molecules in biology (see citations in 9,10). This feature attributable to biological dust shows up not only in our galaxy but in external galaxies as well.

In the context of our claims of a match between astronomical spectral data and an all-pervasive cosmic microbiology such as illustrated in Fig.1 and later in Fig.3, we stress that it is not the simple correspondence of absorption wavelengths in individual functional groups within organic molecules that is claimed here, but rather the integrated absorption/emission spectrum of an entire ensemble of organic functional groups as occurs in a bacterium of a virus. This is not a test used normally by chemists in laboratory spectroscopy, but in the present context remains a powerful argument in support of biology prevailing on a cosmic or cosmological scale.

Another set of astronomical data that has not been explained in nearly 100 years are the diffuse interstellar absorption bands in the optical spectra of stars. The strongest of these is centred at 4430A and has a half-width of ~ 30A. A possible solution to a 100-year old unsolved problem may also be connected with the behaviour of fragmentation products of biology existing under various states of excitation in their electronic configurations. A possible candidate in this category was originally proposed by F.M. Johnson in the form of magnesium tetrabenzo porphyrin (11). More recently a set of other infrared absorption bands in interstellar dust has been found to exist in our galaxy as well as in external galaxies. These are attributed to "polyaromatic hydrocarbon", PAH's but this designation does not explain their origin. A large fraction of the "PAH's" and other organic molecules discovered in the galaxy as well as in external galaxies in our view could represent biological material in various stages of degradation.

The total mass of material tied up in the form of molecules that could have a biological connection in the galaxy (and in the wider cosmos) amounts to possibly a third of all the available carbon – a fraction of a percent of mass of the entire galaxy (12). The question then arises as to whether these biologically relevant molecules so widely present in the cosmos represent steps towards life – prebiotic evolution – or whether they are the products of biological degradation – the detritus of life. The overwhelming bulk of the organic material we find on Earth is unequivocally the result of the decay of biology. So, the question we need to ask is this: Why is it not the same for the organics in space?

Critics who are culturally opposed to think of life as a cosmic phenomenon regard panspermia an "extraordinary hypothesis" and it is stated that extraordinary evidence would be needed to defend such an extraordinary idea. We claim that, on the contrary, confining life to Earth could be regarded as a far more extraordinary assertion, so it is the defence of this latter point of view that must require extraordinary evidence. And such evidence is non-existent, or at best illusory.

The overriding rationale for interstellar dust grains, or a significant fraction thereof, being connected with biology stems from the argument that life itself could only have arisen in a cosmological setting – requiring a volume of space that transcends enormously the miniscule scale of our planet. We then proceed to argue that a cosmologically derived legacy of life along with its full evolutionary potential (contained within the genomes of bacteria and viruses) were introduced via comets onto habitable planets like the Earth in our Milky Way system and beyond. Microbial life thereafter is amplified and recycled between billions of planetary abodes, of which our solar system is just one. Microbial material on this picture must escape continuously into the interstellar medium from comets and planetary systems as indicated in the feedback loop in Fig. 2.

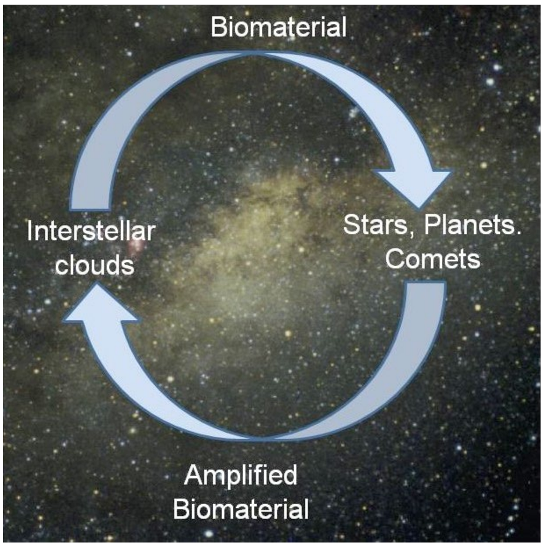


Fig.2 Bacteria and viruses expelled from a planetary system are amplified in the warm radioactively heated interiors of comets and thrown back into interstellar space, where a fraction breaks up into molecular fragments that are observed, but a non-negligible minute fraction remains viable.

**Comets**

The first infrared spectrum of a comet, Comet P/Halley observed in March 1986, showed consistency with bacterial dust emanating from an eruption of the comet (12). More recent studies of other comets have yielded generally similar results. Recently the European Space Agency's Rosetta Mission to comet 67P/C-G has provided the most detailed observations that satisfy all the consistency checks for biology and the theory of cometary panspermia. Fig. 3 shows the close consistency between the surface reflectivity of the comet at infrared wavelengths compared with properties of a desiccated bacterial sample (13).

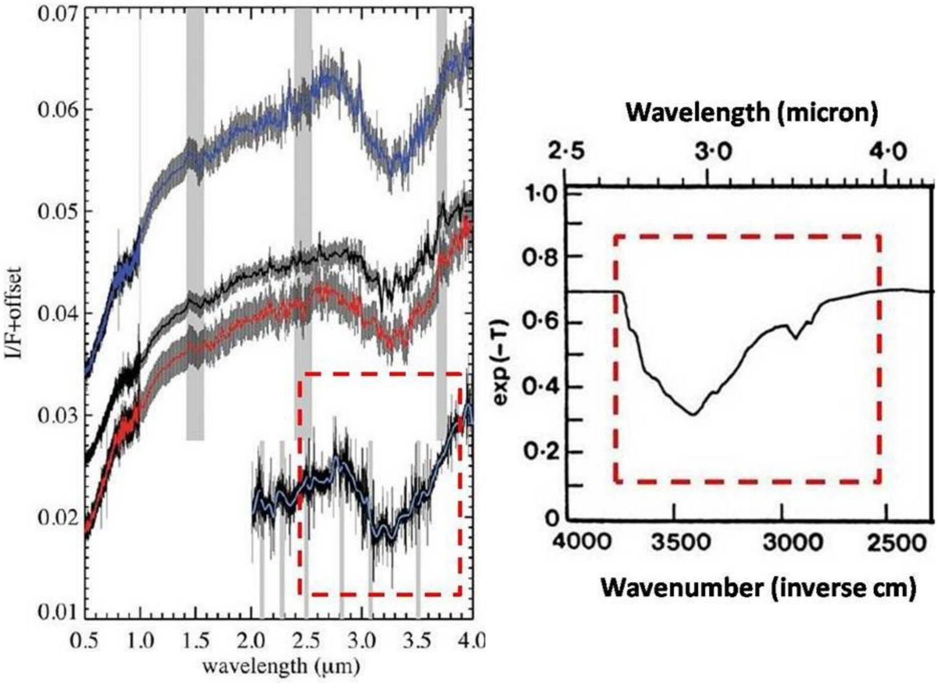


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Fig. 3. The surface reflectivity spectra of comet 67P/C-G (left panel) compared with the transmittance curve measured for *E-coli* (right panel).

It seems ironical that the Rosetta Mission to Comet 67P/Churyumov-Gerasimenko that carried the lander Philae touching down with experiments such as produced Fig.4 did not include a life detection experiment. Some of us, who served on one of the Rosetta mission science teams, had proposed such an experiment similar to the 1976 Mars Viking labelled release detection experiment (14); but as expected this proposal was not included. In the event all we have is tantalising indirect evidence of life as for instance seen in Fig.3 that the critic can choose to ignore as being coincidence. The trouble comes when the number of such "coincidences" escalates to a point where such an assertion begins to look more and more difficult to defend.

More recently the discovery of a giant comet (C/2014 UN271) some 100km in diameter at a distance of 29AU in October 2014 and the later discovery in September 2021 of a dramatic brightening episode offers a further opportunity for verifying the predictions of fermentation processes in a "biological" comet (15) The eruptions of the comet at a heliocentric distance of 20AU (two thirds of the distance from the sun to Neptune) can only be plausibly explained as due to high pressure venting of the products of microbial metabolism in radioactively heated subsurface lakes.

Carbonaceous meteorites (residues of comets) and other bodies in the solar system have also come under close scrutiny over the past few decades. Space Missions combined with laboratory investigations have provided clear evidence for liquid water and indigenous extraterrestrial organics and biomolecules in carbonaceous chondrites as well as in low density asteroids (Hoover et al, 2022; ref 16). Recent discoveries of biomolecules including amino acids and nucleobases (purine and pyrimidine) in some carbonaceous asteroids and meteorites (17) have been hailed as supportive evidence for a biological connection, although in a limited and in our view flawed context of supplying merely the components of a primordial soup on Earth. Scanning Electron Microscope studies over the past few decades have provided clear evidence of indigenous microfossils in diverse groups of carbonaceous meteorites but they tend to be ignored or dismissed. Thus, the long-held culturally sanctioned Aristotelean belief that terrestrial life must necessarily start *de novo* remains hard to shake off (4,7).

**Stratospheric evidence**

If comets are the repositories of cosmic life the question arises as to whether this proposition is open to test and verification at the present time. The Earth's orbit continually crosses streams of cometary debris so is it possible to detect bacteria in our neighbourhood, perhaps in the stratosphere? To answer this question one of us (JVN) approached the Indian Space Research Organisation (ISRO) in 2000 seeking their collaboration to make the first carefully controlled recovery of microbial structures (bacteria and putative viruses) from a height of 41km in the stratosphere, presumably falling in from space and of extraterrestrial/cometary origin.

The startling conclusion from this sampling experiment was that positive detections of in-falling microbiota collected in a measured volume of the stratosphere at 41km led to an estimate of an in-fall rate over the whole Earth of 0.3-3 tonnes of microbes per day. This converts to some 20-200 million bacteria per square metre arriving from space every single day (18,19). Between 2001 and the present day this infall rate of microbiota would appear to have been amply confirmed, although not still widely admitted.

The results from the first ISRO-sponsored balloon flight in 2001 (see Shivaji et al. [20]) included a further significant finding. The bacteria isolated by CCMB (Centre for Cellular and Molecular Biology, India) were uncannily resistant to ultra violet radiation. This indicated that these microorganisms evolved in the presence of UV radiation, thus making it very unlikely that they came from the surface of the Earth with only a short residence time (without replication) in the stratosphere.

Following the first 2001 ISRO balloon launch a second stratospheric sampling flight was carried out in 2005 (20,21) when 12 species of bacteria were found at a height of 41km in the stratosphere. Of these three were entirely new in the sense that they had never been identified on the Earth. They were named after Fred Hoyle, Aryabhata (the 5$^{th}$ century Indian astronomer) and ISRO (21). Currently an ISRO-based team is in the process of using nanotechnology to devise ways of isotope analysis to distinguish unequivocally between terrestrial and extraterrestrial microorganisms.

**The canonical cosmological context**

We have consistently argued over many years that in order to understand the origin of the super-astronomically vast and complex informational system as we find in biology it is imperative to go to the "biggest" available system in which such information can be generated. That system is unquestionably the entire universe, and so biology and cosmology must come to be understood as being inextricably linked. The cosmological backdrop against which this link has to be understood has evolved over a nearly a century. In 1929 Edwin Hubble discovered the relationship between the distances of faraway galaxies and the redshift of their spectral lines. The latter was interpreted as Doppler shift due to recession with a connection thus established between velocity of recession – speed at which galaxies were rushing away from one another - and their absolute magnitude or intrinsic luminosity. This led to the concept of an expanding universe, with "Hubble's law" defining the rate at which the universe appears to be flying apart from an initial origin as a "point". Reversing the speeds of expansion as indicated by Hubble's law soon led to an estimated age of the universe of some 13.7 billion years and to the concept of "Big Bang Cosmology" – everything we find in the universe starting off as a point. Such a mathematical point containing all the energy and all the information for physics as well as biology remains a concept of origination that by its very essence cannot be further explored. However, in one form or other this is the model of the universe that has come down to be regarded as the scientific orthodoxy which everyone is supposed to accept in the present day. It will be disingenuous to deny that cultural considerations have played a decisive role in controlling the scientific narrative. To sum up, the prevailing orthodoxies in both cosmology and biogenesis continue a strictly Aristotelean tradition, which incidentally accords well with a Judeo-Christian world view – "God said let there be light and…."

The discovery of the *cosmic microwave background* radiation (CMB) by Penzias and Wilson (22) came to be regarded as the transformative evidence supportive of the standard Big Bang theory of the origin of the universe - the afterglow of light and radiation left over from the infinitely hot Big Bang cooled down to a temperature of 3.5K. It is this evidence that was used to challenge the rival steady-state cosmology advocated by Hoyle and one of us (JVN) in subsequent decades. Alternative mechanisms for explaining the microwave background data were never popular, and the Big-Bang cosmological model, sanctioned by a strong cultural tradition, became firmly rooted in astronomy. The autobiographical reviews by one of us (JVN) will serve to outline how scientific prejudice operates [23-27]. The 'bang wagon' effect has led to a 'confirmed belief' in big bang cosmology. In this context we also commend in particular an article by Fred Hoyle [26] giving a 'mathematical' analysis of how belief in a paradigm grows despite lack of real evidence.

The progression of energy/matter from the postulated Big Bang event to atoms, stars and galaxies has been fertile ground for cosmologists over many decades. The first phase known as inflation leads to a rapid succession of doublings the formation of light elements a quiescent phase known as the "dark ages", re-ionisation, and the formation of the first stars and galaxies. The last of these steps was not conceived of as happening prior to some 400 million years following the "Big Bang" event.

**Alternative cosmological models**

It is not widely recognised in the scientific world that ideas relating to an infinite age of the universe and models involving an infinite sequence of creation and destruction episodes have a distinct Indian provenance.

According to Carl Sagan:

*"The Hindu religion is the only one of the world's great faiths dedicated to the idea that the Cosmos itself undergoes an immense, indeed an infinite, number of deaths and rebirths. It is the only religion in which time scales correspond to those of modern scientific cosmology. Its cycles run from our ordinary day and night to a day and night of Brahma, 8.64 billion years long, longer than the age of the Earth or the Sun and about half the time since the Big Bang. And there are much longer timescales still……"*

*(Cosmos: The Story of Cosmic Evolution, Science and Civilisation. 1983)*

*Jain and Buddhist* traditions (500 BCE) also follow the same thought with cyclical universe and were most probably continued from the earlier Hindu texts.

In this context it is worth reiterating that the currently favoured Big-Bang theory of the Universe with an age of 13.8 billion years is by no means absolutely proved. The very recent discovery of a galaxy designated GN-z11 located at a distance of 13.4 billion light years (implying its formation just 420 million years after the posited Big Bang origin of the Universe) poses serious problems for the current consensus view of cosmology (28). Similar problems for the Big Bang cosmological model have been discussed over a period of some 3 decades by small group of dissenters (29).

Recently Nobel Laureate Roger Penrose has come in among the select band of dissenters from the standard view of a unique Big Bang origin of the Universe 13.8 billion years ago (30,31). In a theory called the "conformal cyclic cosmology" Penrose postulates that the universe undergoes an infinite number of cycles in which the Big Bang event 13.8 billion years ago is the most recent cycle of which we are a part. The difference between the Penrose models and those of Hoyle and Narlikar involving quasi-steady-state cosmologies do not appear to be vast (24).

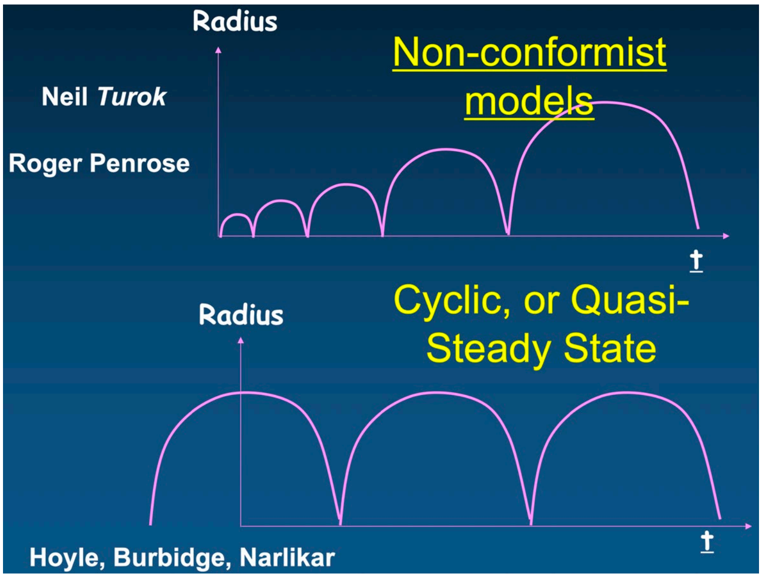


Fig.4. Schematic depiction of non-conformist models of the Universe
Both theories posit cyclic models that are in general coincidentally consonant with ancient Vedic-Hindu ideas.

The James Webb Space Telescope that came into operation this year was designed to look farther back in space and time than any other telescope, so it is not surprising that it may have detected the most distant galaxy in the cosmos (28). The object known by the designation CEERS-93316, a galaxy – if indeed it is confirmed as a galaxy – will be some 35 billion light-years away. We have now gone back in time from 400 million years after the Big Bang in the case of GN z-11 to a staggering 235 million years proximity to the Big Bang. This moment is only about 135 million years after the first stars are thought to have been born.

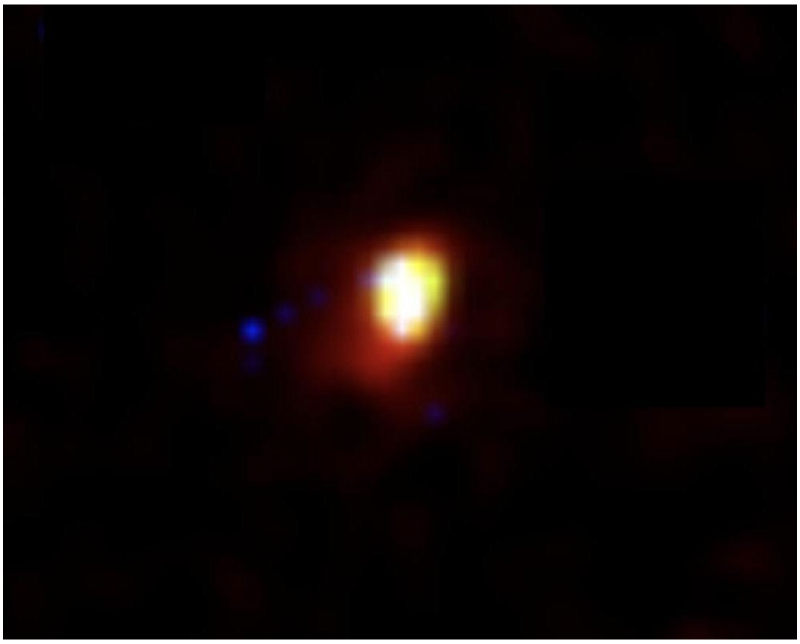

Fig. 5. CEERS-93316 presumed to be the most distant galaxy discovered thus far, implying it is now at a redshift of z=16.7 implying it is now at a distance of ~ 35 billion light-years from Earth (courtesy NASA) (28).

One might wonder how such a distance is plausible. The universe is only 13.8 billion years old, how can anything be farther away than that? The answer is that the universe has expanded greatly since the light first left the galaxy about 13.6 billion years ago, so that the "proper distance" to CEERS-93316 now is in fact 35 billion light-years. This new data already poses severe problems for standard Big-Bang models of the Universe. But there would surely be more surprises in store – even older galaxies where none is expected, and hopefully spectroscopic data clearly pointing to life at the very dawn of time.

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