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The Second Copernican Revolution

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The recent discovery by the James Webb Space Telescope of organic molecules possibly related to life in a galaxy at redshift z=12.4 may well signal a concluding phase of the second Copernican revolution, thus removing the Earth from the centre and focus of biology and charting a new course in our understanding of the universe, and concluding a process that began 4 decades ago.

Keywords: Panspermia, cosmology, astrobiology, origin of life

1. Introduction

*"It appears to me to be a 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 just as old as matter itself…"*-

Herman von Helmholtz (1821-1894)

Forty years ago, Fred Hoyle and one of the present authors (CW) challenged what was essentially regarded as the bedrock of Western culture and science – the origin and evolution of life interpreted in a narrow terrestrial setting (1-10). The idea of life emerging on Earth spontaneously from inorganic material constituted the central core of Aristotelean philosophy and had dominated western thinking for over two millennia. Yet a veritable tide of new facts from astronomy and molecular biology that emerged after the dawn of the space age in the 1960's led Hoyle, Wickramasinghe and their collaborators to seriously question this reigning dogma.

From the early 1980's Hoyle, Wickramasinghe and others followed a path that had seemed too daunting for their predecessors in former times, forging what could be seen as a merger of astronomy and biology, and thus leading to the birth of the new discipline of astrobiology (5-10). This chosen path was beset with societal disapproval on a scale that had not been witnessed for a long time. However, encouragement to continue and not to be deflected from an intended path was derived not from individuals as such, but from new scientific facts that still continues to emerge from diverse disciplines – geology, biology and astronomy itself.

A related paradigm that took centuries to overcome also had Aristotelean roots – the premise that the Earth was the centre of the solar system and centre of the Universe itself. The Copernican revolution in astronomy started with Galileo and Copernicus and was concluded with Kepler and Newton, spanning the time interval 1500-1700CE, nearly 200 years.

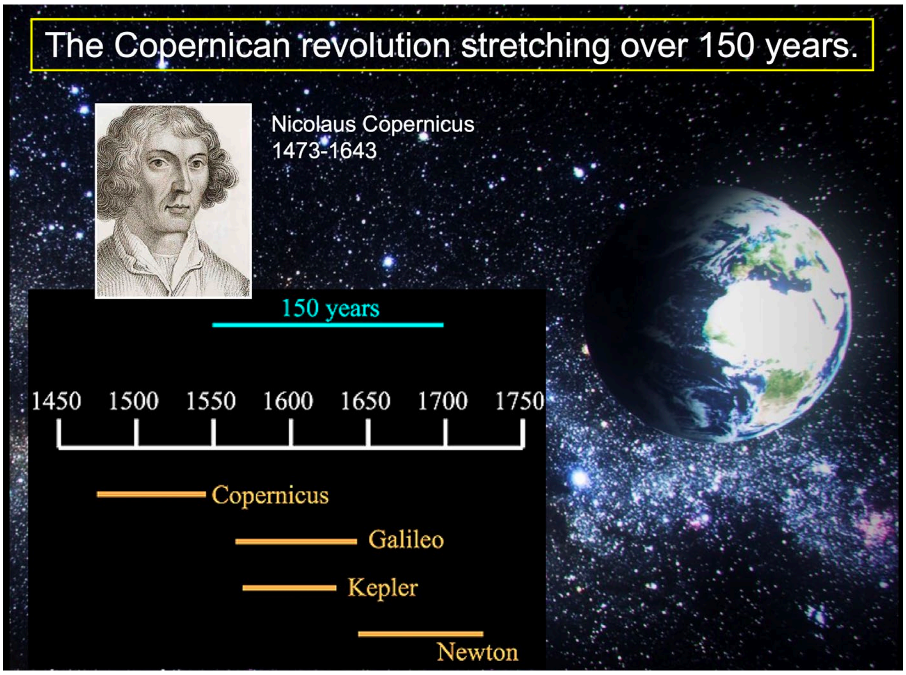

Fig. 1. Trajectory of the first Copernican revolution that removed Earth from the centre of the solar system and Universe.

This "first" so-called Copernican revolution displaced the Earth from its earlier hallowed status of centrality in the cosmos. The developments in astrobiology and cosmology over the past four decades could be seen to define the second and final part of the same Copernican revolution, one that now seeks to remove Earth from the centre of biology and advance the proposition that *life is a cosmic phenomenon*.

2. Modern resurrection of Panspermia

Panspermia is an ancient idea that has had a chequered history from its first emergence in the canon of pre-Socratic philosophy with the pronouncements of Anaxoragas in the 5th century BCE. Nearly two centuries later, the far more influential Greek Philosopher Aristotle effectively took control of philosophy over an exceedingly broad front, and consequently his rejection of panspermia and support for the rival theory of spontaneous generation dominated Western thinking in this area almost to the present time.

Panspermia of course had many staunch advocates who emerged sporadically through the centuries (Wickramasinghe et al, (9); Wainwright and Wickramasinghe, (10)). Perhaps the most notable amongst them was the French biologist Louis Pasteur who challenged Aristotelean spontaneous generation over a century ago (11). From Pasteur's laboratory studies on the growth of microorganisms in broths he confidently concluded with the strongly positive declaration *"Omne vivum ex vivo*", which means 'Life [is] from Life' in 1864. This claim was of course vigorously refuted by most biologists in the early 20th century, but as the decades progressed and with the emergence of new evidence from biology and astronomy, one of the present authors (CW) together with Hoyle and his collaborators were able to reaffirm the same position.

As with the first Copernican revolution, and indeed all earlier major paradigms throughout history, "wrong" ideas about the nature of the world that have become entrenched and been in currency for extended periods have always been difficult to displace. The old ideas are passionately adhered to and vigorously defended until, with the advent of new facts, they must of necessity eventually come to be overturned. The same, we believe, will undoubtedly be true today in relation to all the "big ideas" about the world. One such big idea is Aristotle's theory of the spontaneous generation of life. This theory led naturally to the firmly entrenched modern belief that life is a purely terrestrial affair – a trivial and obvious assembly of atoms – atoms that were of course synthesized through nuclear processes in the deep interiors of stars. The first cells to "emerge" spontaneously from such atoms, cells from which all the rest of life eventually evolved, is assumed to arise as a result of chemicals coming together *spontaneously* to form "life" in some location on Earth – margins of oceans, lakes, ponds or geothermal vents. Yet, it goes without saying there is, and never was, any substantive evidence to support such a belief.

What is usually ignored, or at any rate consistently glossed over, is the astronomically vast information content (in the form of the *specific arrangements* of the relevant monomers) that is involved in formation of even the simplest living cell (2). In present-day biology, the so called "Shannon information" contained in enzymes—the specific arrangements of amino acids in folded chains—is crucial for the functioning of life, and this information is transmitted by means of the coded ordering of nucleotides in DNA. In a hypothetical RNA world, that may have predated the DNA-protein world, RNA is normally posited to serve a dual role as both enzyme and genetic transmitter. If a few 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^{80}, which can hardly be supposed to happen even once in the entire 13.7-billion-year history of the universe.

The biggest problem relating to the origin of life is to overcome an astronomical or super-astronomical improbability hurdle that demands stochastic resources not available on the Earth. The Earth of course is an open system inextricably linked to the external universe by continually receiving material inputs in the form of cometary dust, meteorites etc; and as we now know, following studies with the Kepler space telescope, the solar system is within easy reach/connection of billions of other habitable planets in the galaxy. There is thus no logical requirement any more to insist that life necessarily started on Earth.

The conventional and societally sanctioned idea of life originating *de novo* on Earth can only be defended by placing the Earth in a unique and special position in relation to the occurrence of perhaps the most improbable of cosmic events. In the exceedingly unreal circumstance that no "bigger" probability space is available for such an event we might even be forced to adopt an anthropic argument in this context and say: "We are here on the Earth, so life *must* have started here no matter how improbable that might be".

Since the discovery of DNA by Francis Crick in the 1950's, combined with the discovery and sequencing of enzymes, the informational hurdle to overcome in transiting from life from non-life came into sharp focus (2). The precise ordering of nucleotides in DNA, or correspondingly the arrangement of amino acids in enzymes, poses a difficulty that can only be resolved if we are permitted to extend the domain (or domains) for life's origin to encompass cosmic or even cosmological dimensions. Within such a domain of cosmic (or even infinite) proportions, the superastronomical informational hurdle for starting life *could* be somehow overcome.

Removing the Earth from the centre of biology in such a way would arguably constitute the *second and ultimate Copernican revolution.*

When organic molecules were first discovered in interstellar clouds in the 1960's it might be said that the die was cast for abandoning the Earth-centred view of life. Contemporaneously with the discovery of interstellar organic molecules of ever-increasing complexity, a major paradigm shift in astronomy was being spear-headed by Fred Hoyle and one of the present authors (4-6). At this time the strongly held astronomical opinion was that interstellar dust was comprised of ice grains that condensed in interstellar clouds. A combination of mathematical modeling and astronomical observations led over the decade 1962-1972 to a transition from the old ice particle model of interstellar dust to a model involving mixtures of carbonaceous and siliceous grains. From 1974 onwards, the interstellar dust models began to include a large component in the form of organic polymers – eg polyoxymethyline, polysaccharides (5, 6).

In the late 1970's the time seemed right to confront the long-held view that life originated on the Earth by expanding the canvas for life's origin to span the biggest available galactic distance scales. Laboratory evidence demonstrating the incredible space-survival attributes of bacteria and viruses was accumulating to support such a model. It could be argued then that once life had originated in a cosmic setting its subsequent spread and perpetuation was inevitable. These ideas were tantamount to a revival and radical re-casting of the ancient idea of panspermia, with comets playing a crucial role in the amplification and dispersal of life on a galactic scale (6-10). The new science of astrobiology was born at about the same time (7).

If habitable planets were commonplace, which we did not know at the time, but now know, the entire galaxy will become a single connected biosphere on a relatively short timescale (9). The time scale could be as short as 240 Myr which is the period of rotation of the solar system around the centre of the Galaxy, during which mixing of biological material between planetary systems would inevitably occur. The adoption of such a point of view regarding the astronomical origins of life would surely open up new vistas of research in astronomy as well as biology.

This is the "Brave New World" approach that still continues to be resisted by many in the scientific community for reasons that lie well outside the realm of science. Supportive scientific evidence for the idea itself has accumulated steadily over the past 4 decades from widely different areas of science – astronomy, biology, geology. However, each individual piece of evidence supporting such a cosmic origin of life can be interpreted, if one so chooses, in a conservative manner that might, albeit imperfectly, preserve the *status quo*. We would therefore quite naturally expect to see a series of major confrontations with authority in an attempt to deny or delay an inevitable conclusion. This is precisely what happened.

3. Data from interstellar dust

An astronomical dataset that has not been explained satisfactorily for over a century relates to the so-called diffuse interstellar absorption bands (DIB's) in the optical spectra of reddened stars. The strongest of these is centred at the wavelength 4430A and has a half-width of ~ 30A (12, 13). A possible solution to this 100-year old mystery is most likely to be connected with cosmic biology, a proposition that had been considered inadmissible from the very outset. This involves the behaviour of fragmentation products of biology existing in interstellar space under various conditions of excitation in their electronic configurations. A possible candidate in this category was proposed by F.M. Johnson in the form of molecule magnesium tetrabenzo-porphyrine (12, 13), a molecule related to chlorophyll that is of course a molecule crucial for photosynthetic biology. It is no surprise in this context that the overwhelming biomass of the Earth is in the form of chlorophyll-containing plants, algae and photosynthetic biology making up over 99.999% of the total.

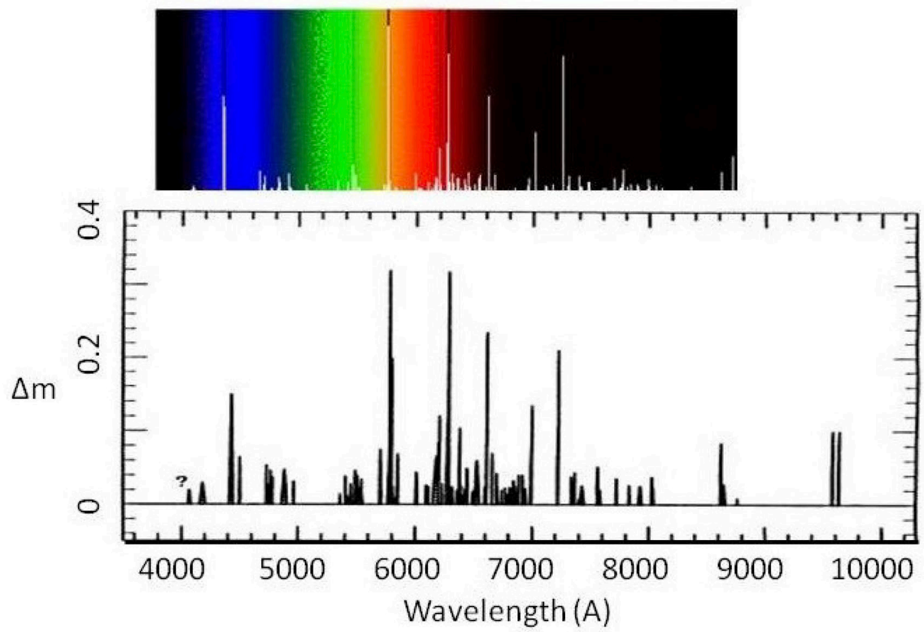

Fig.2. The diffuse interstellar bands with half widths 2-30A are distributed over the entire visual waveband. They are correlated with interstellar extinction but have defied identification for nearly 100 yr (see ref.12, 13).

The next confrontation with authority involved the interpretation of the interstellar extinction curve – the precise manner in which the continuum radiation of distant stars is scattered and absorbed by interstellar dust over a wide wavelength range from the infrared to the far ultraviolet. From the early 1970's onward, one of the present authors (NCW) had been working on the problem of interstellar dust for over a decade and was becoming increasingly uncomfortable with the attempts that were made thus far to theoretically model the data with inorganic dust models – particularly ice particles (4, 5, 6, 12). The fits of all such models to astronomical data were always less than perfect, and the assumptions required to obtain even imperfect fits were often too arbitrary and *ad hoc*.

In the late 1970's the emphasis shifted away from "dirty ice grains" to the possibility that a significant fraction of interstellar dust had an organic composition with biological connotation. With such models one of us (CW) was able to obtain impressively close fits to astronomical data and with a minimum of free parameters to fit.

One prediction of the organic model of interstellar dust was that the mid-infrared spectrum of an infrared source seen through a few kiloparsecs of dust obscuration should reveal a spectrum of bacterial material. In 1981 this prediction was dramatically verified at the Anglo-Australian Telescope by D.A. Allen and Dayal Wickramasinghe (14) (CW's brother) to a degree of precision that seemed stunning. This crucial fit is shown in the left-hand panel of Fig.3.

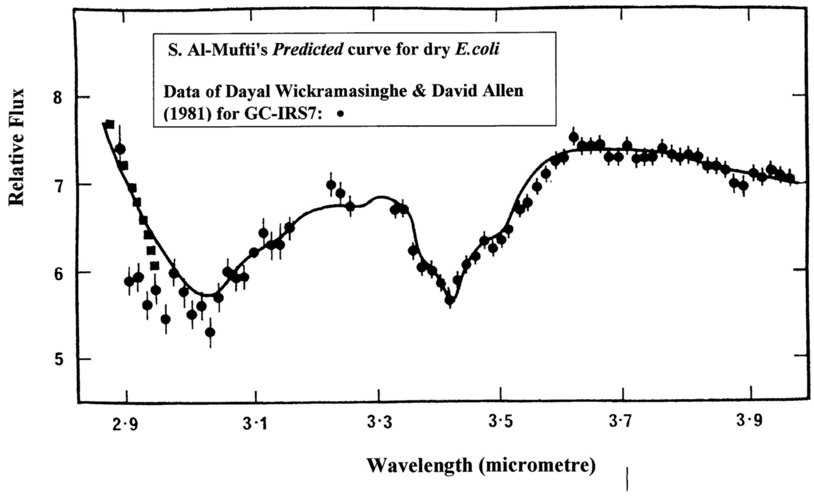

Fig 3. The first detailed observations of the Galactic centre infrared source GC-IRS7 (Allen and Wickramasinghe, 1981 (14) compared with earlier laboratory spectral data for dehydrated bacteria.

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Later predictions for cosmic dust models with a biological provenance included an ultraviolet peak in the interstellar extinction curve at the wavelength 2175A which Hoyle and one of us (CW) attributed to bicyclic aromatic molecules (eg pyran rings in biology) (15). This feature was thus elegantly explained on the basis of biological dust models. Subsequently the prevalence of a similar UV dust feature in galactic dust and also dust in distant galaxies lent strong support to the concept of life as a cosmic phenomenon. Fig. 4 shows the appearance of this UV extinction feature in our galaxy as well as in external galaxies up to relatively high redshift values, implying in our view, that biological dust was present on a vast extragalactic scale (16, 17).

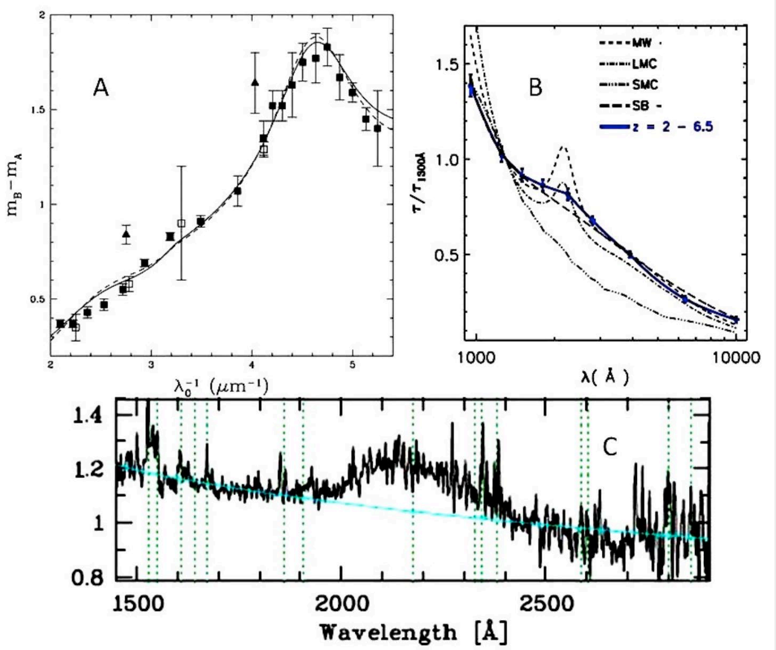

Fig. 4. Ultraviolet extinction curves for high redshift galaxies showing the 2200A feature which we attribute to biology. A: Motta et al (16) galaxy at z=0.83 (14); B: Stack of "normalised" extinction curves compiled by Scoville et al (17) for our galaxy (MW), LMC, for starburst galaxies (SB) and for the average of all high redshift galaxies with z in the range 2-6.5.

4. PAH molecules in space and Extended Red Emission of interstellar dust

The existence of PAH's (polyaromatic hydrocarbons) both in interstellar clouds within our galaxy and in extragalactic sources have also been known for over 3 decades, and in our view, this has been incorrectly attributed to a non-biological origin. Biological aromatic molecules in the form of PAH's would be a natural result of the degradation of biological dust (bacteria and viruses) which we have argued makes up over 10 percent of carbon in interstellar space (7). Also linked to PAH's is the phenomenon of extended red emission (ERE) that has been observed in many extended astronomical sources (Witt & Schild 1988 (18); Furton & Witt 1992 (19); Perrin et al. 1995 (20)). These sources, including the Red Rectangle, emit radiation at red wavelengths that is readily explained on the basis of biological pigments. The biological aromatic model still remains the most reasonable explanation for this entire data set (3, 19, 20).

Competing models based on emission by compact PAH systems, derived non-biologically, are not as satisfactory, as is evident in Fig. 5. Hexa-peri-benzocoronene is one of a class of compact polyaromatic hydrocarbons that have been discussed in this connection. However, the width and central wavelength of its fluorescent emission show a significant mismatch.

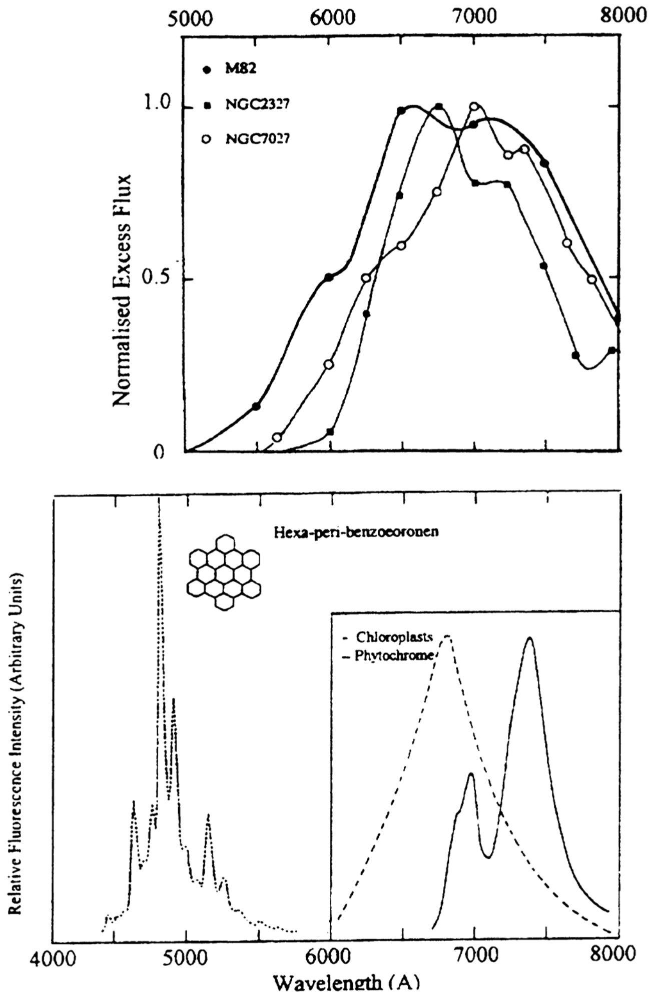

Fig. 5 Extended red emission (ERE). The points in the top panel show normalised excess flux over scattering continua from data of Furton and Witt (19) and Perrin *et al.* (20). The bottom right panel shows relative fluorescence intensity of spinach chloroplasts at a temperature of 77 K. The dashed curve is the relative

fluorescence spectrum of phytochrome. The bottom left panel is the fluorescence spectrum of hexa-peri-benzocoronene.

PAH (polyaromatic hydrocarbon) absorption bands are found in dust clouds in the Galaxy and in external galaxies up to high redshift values. The persistent PAH features in 13 starburst galaxies studied by Brandl et al (21) are shown in Fig. 6. Although the general preference among astronomers has been to interpret these features as the products of non-biological chemical processes such an explanation is far-fetched compared to the idea that they are the degradation products of biology.

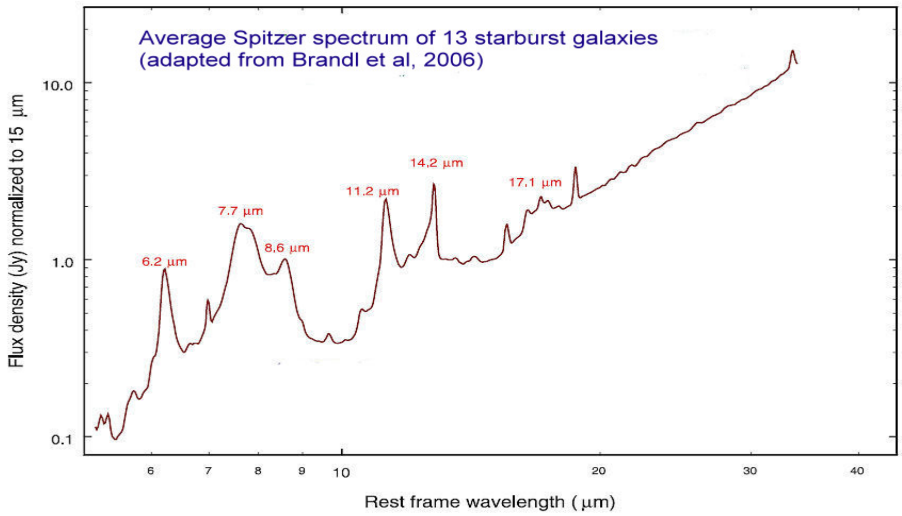

Fig. 6. Averaged *Spitzer* IRS spectrum of 13 starburst galaxies (21).

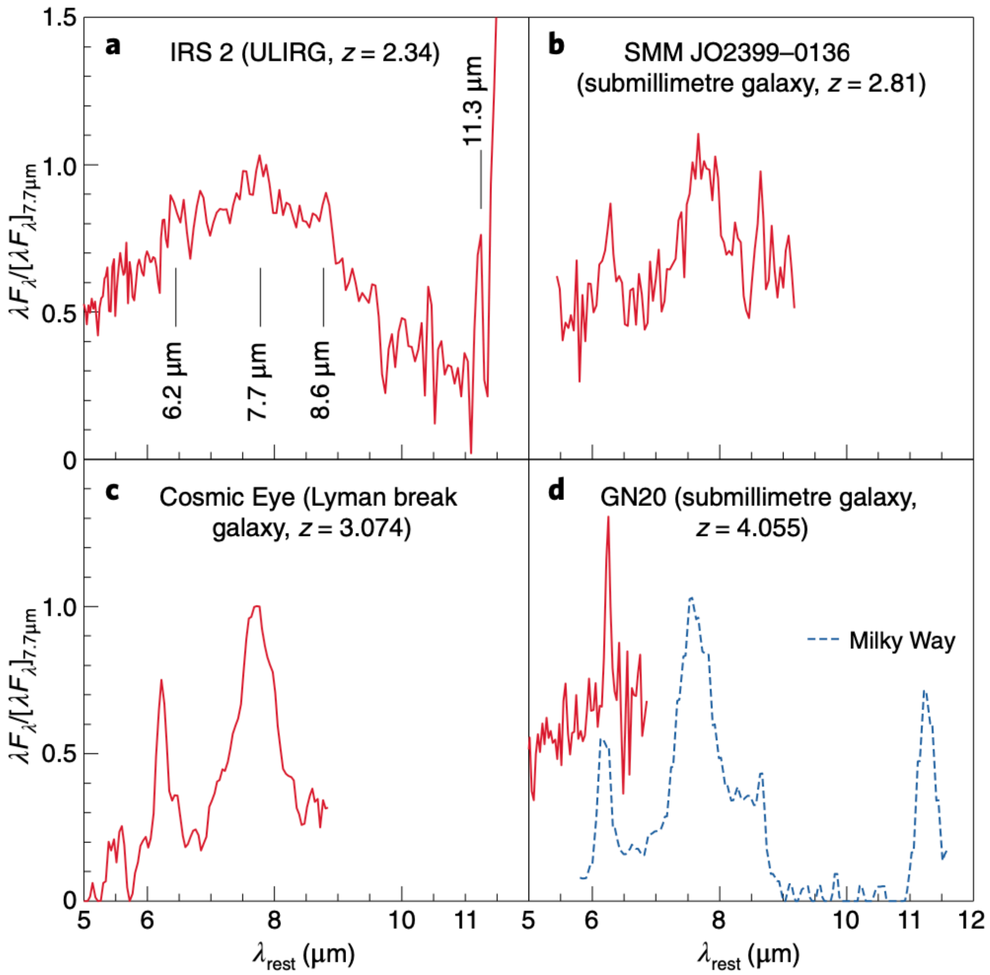

Fig. 7. Spitzer/IrS rest-frame spectra of galaxies at various redshifts (a) ULirG irS 2 ($z = 2.34$); (b) Submillimetre galaxy SMM J02399−0136 ($z = 2.81$); (c), Lyman break galaxy Cosmic Eye ($z = 3.074$); (d), Submillimetre galaxy GN20 ($z = 4.055$). Also shown in (d) is the I SOPHOT spectrum of the Galactic diffuse ISM (blue dashed line).

Fig.7 shows the PAH spectra of several high redshift galaxies recently compiled by Li (22), with wavelengths reduced to rest frame values. Also shown in the blue curve (7d) is the diffuse PAH emission from Milky Way. The vast quantities of PAH-type molecules and other organic molecules on the Earth are, in our view, unequivocally the degradation products of biology. To resist the same conclusion – even provisionally - for similar carbonaceous molecules that have been discovered in astronomy (galactic as well as extragalactic) for over 4 decades is unnecessary, to say the least, and is the reflection of the strongly entrenched pre-Copernican and strictly Aristotelean view of cosmic biology.

The most recent claim of "evidence of pre-biology" involves the detection of the ion CH3+ in a protoplanetary disk, and is yet another case in point (Spiker et at, 23). (See also: https://www.esa.int/Science_Exploration/Space_Science/Webb/Webb_makes_first_detection_of_crucial_carbon_molecule_in_a_planet-forming_disc). This new discovery is being hailed as signalling the operation of the super-astronomically improbable process of spontaneous generation, but there is no evidence whatsoever to support the causal link:

Organic molecules in protoplanetary disk → origin of life.

This most recent JWST discovery, along with the other features discussed earlier, must all be regarded as representing the detritus of life, in various stages of its inevitable degradation under cosmic conditions. It is, however, inevitable that such detritus will be available for the generation of biospheres on newly forming habitable planets, just as detritus of terrestrial life nurtures new life. This would be more relevant in the case of complex molecules that are involved in the ERE phenomenon (Witt and Schild (18)) and also the well-known diffuse interstellar features (12, 13) that have defied understanding for close on a century. However, we must stress that new life requires a full superastronomical content of Shannon information that must be supplied by an eternally present component of intact RNA and/or DNA which must in all likelihood be regarded as ever present in the cosmos. Such information must be, in the words of Helmholtz, "just as old as matter itself".

5. Completion of the Second Copernican Revolution

The overwhelming body of evidence for the enormous abundance of organic molecules in space – in comets, interstellar space and in external galaxies cannot fail to impress an impartial observer that we are facing an age-old cultural conflict – life as a cosmic phenomenon *vs* life as being purely terrestrial. Needless to say, all this evidence and in particular and the verification of our predictions of a biological model of interstellar dust (eg. Fig.3) continues to be vigorously resisted within mainstream astronomy. A non-biological explanation of the points in Fig. 3 would require inorganically formed organic molecules to possess functional groups that fortuitously mimic biology against the most impossible odds. Similar arguments have also been advanced for every subsequent discovery of astronomical spectra that matched biological material for example the data in Figs. 4-7.

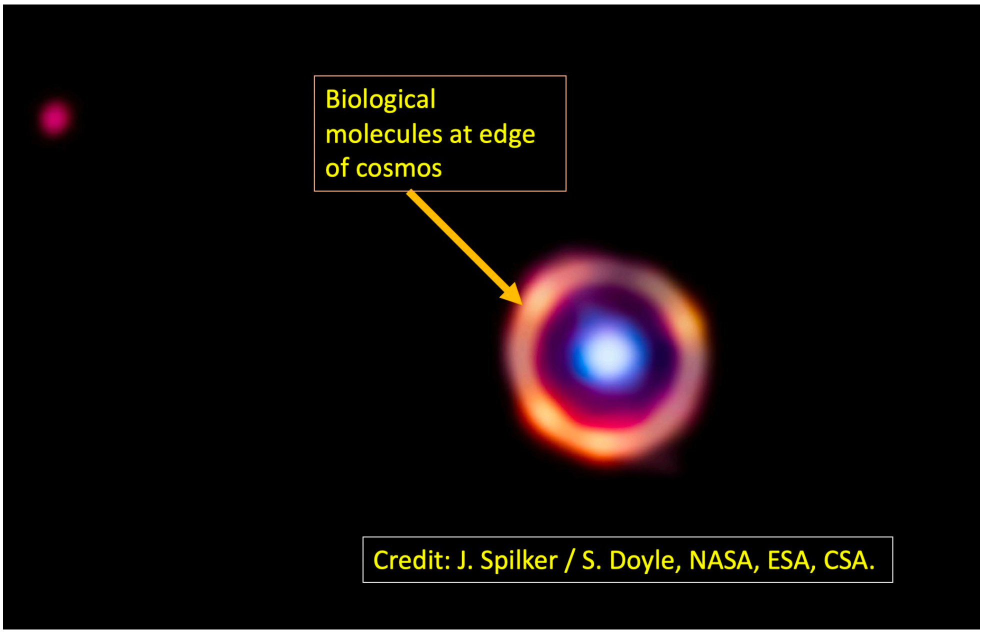

Fig.8. Einstein ring image of galaxy SPT0418-47, within which poyatomatic hydrocarbon molecules were detected (*Image: J. Spilker / S. Doyle, NASA, ESA, CSA)*

Perhaps the most dramatic result to come from the James Webb Space Telescope (JWST) is the detection of complex organic molecules in a galaxy 12.3 billion light-years away (SPT0418-47) that was fortuitously gravitationally lensed by a foreground galaxy (23). The new observation indicated that SPT0418-47 was rich in heavy elements as well as complex organic molecules (PAH's). Such life-related molecules now reside a galaxy that formed when the universe was less than 10% of its current age. The light bearing spectroscopic signatures of these molecules began its journey scarcely 1.5 billion years after the putative Big Bang – if that indeed was the ultimate origin of the Universe. As we have seen in this review, evidence of complex organic molecules in external galaxies has accumulated over the past 3 decades but not beyond redshifts greater than z=4. The astronomical orthodoxy has maintained without proof that such molecules must necessarily be the result of non-biological chemical processes involving gas-phase reactions in interstellar clouds, but well-attested evidence now clearly supports the interpretation that Hoyle and one of us had suggested 40 years ago - namely cosmic organic molecules can plausibly arise only from the degradation of life itself – bacteria and viruses degrading under conditions prevailing in space.

With so many different and independent data sets and lines of evidence, all pointing to life as a cosmic phenomenon as a preferred option, and particularly with the new detection of organics in a galaxy uncomfortably close to the putative Big Bang event, the case for an Earth-centred origin of life is beginning to look ever more insecure. Life is a cosmic phenomenon, with the stark possibility that must be left open – both the Universe and life within it had no beginning!

The ultimate Copernican revolution has been completed and it will be the privilege of future generations to reap the benefits of this momentous transition.

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