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GOLDEN RATIO BEAUTY AS SCIENTIFIC FUNCTION

1. Introduction

Normally when one is considering the golden ratio in the history of ideas, one is often looking at it as an aesthetic principle – usually associated with Greek art, sculpture and mathematics. However, in recent years the prevalence of the golden ratio within a broad range of scientific disciplines has brought its role in the perfection of science to the forefront. I would like to collapse these two areas by proposing a somewhat novel way of looking at the aesthetics of the golden ratio: its pervasive expression in scientific form and function is the basis of the aesthetics in the world. Therefore, science contains the same mathematical beauty as found in artistic expression.

Plato, in the *Timaeus* 31b-32a, makes it clear that the geometric mean is nature's primary bond: «Two things cannot be rightly put together without a third; there must be some bond of union between them. And the fairest bond is that which makes the most complete fusion of itself and the things which it combines, and proportion (analogia) is best adapted to effect such a union». And it is the golden ratio that produces the simplest geometric mean of all. This utter sublimity of the golden ratio can be further seen in the following. It is both the simplest continued fraction (Figure 1) and simplest nested radical (Figure 2). When the golden ratio is used as the basis for an additive series, it uniquely is both additive and multiplicative (Figure 3). No other number has these properties.

$$\Phi = 1+\cfrac{1}{1+\cfrac{1}{\Phi}} = 1+\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{\Phi}}} = 1+\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{1+\ldots}}}}}}}$$

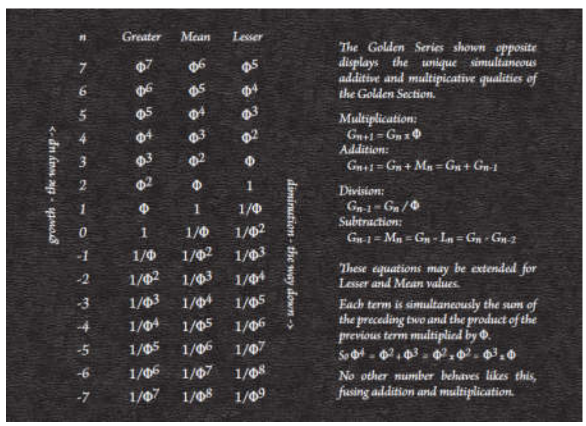
FIGURE 1: Simplest Continued Fraction

$$\Phi = \sqrt{1+\sqrt{1+\Phi}} = \sqrt{1+\sqrt{1+\sqrt{1+\Phi}}} = \sqrt{1+\sqrt{1+\sqrt{1+\sqrt{1+\sqrt{1+\sqrt{1+\ldots}}}}}}$$

FIGURE 2: Φ as Simplest Nested Radical

In fact, the prevalence of the golden ratio in the sciences suggests that it is the fundamental source of all beauty. It guides the Chaos Border of Kolmogorov, Arnold, and Moser (KAM theorem) and it can be found hidden in all elementary particles, and even in the proportions of dark matter and energy relative to visible matter and energy. It is evident in the structure and growth functions of plants and animals and it can be found in the physiological functions of humans. It now appears that without the golden ratio, we would not have the form or function of the proton, cell, athlete, horse, species, planet, solar system or galaxy. The following include examples of the golden ratio expressing perfection, efficiency and effectiveness, i.e. beauty, throughout the sciences.

FIGURE 3: **Golden Ratio Properties**



n	Greater	Mean	Lesser
7	Φ^7	Φ^6	Φ^5
6	Φ^6	Φ^5	Φ^4
5	Φ^5	Φ^4	Φ^3
4	Φ^4	Φ^3	Φ^2
3	Φ^3	Φ^2	Φ
2	Φ^2	Φ	1
1	Φ	1	$1/\Phi$
0	1	$1/\Phi$	$1/\Phi^2$
-1	$1/\Phi$	$1/\Phi^2$	$1/\Phi^3$
-2	$1/\Phi^2$	$1/\Phi^3$	$1/\Phi^4$
-3	$1/\Phi^3$	$1/\Phi^4$	$1/\Phi^5$
-4	$1/\Phi^4$	$1/\Phi^5$	$1/\Phi^6$
-5	$1/\Phi^5$	$1/\Phi^6$	$1/\Phi^7$
-6	$1/\Phi^6$	$1/\Phi^7$	$1/\Phi^8$
-7	$1/\Phi^7$	$1/\Phi^8$	$1/\Phi^9$

growth - the way up ->

diminution - the way down ->

The Golden Series shown opposite displays the unique simultaneous additive and multipicative qualities of the Golden Section.

Multiplication:
$G_{n+1} = G_n \times \Phi$

Addition:
$G_{n+1} = G_n + M_n = G_n + G_{n-1}$

Division:
$G_{n-1} = G_n / \Phi$

Subtraction:
$G_{n-1} = M_n = G_n - L_n = G_n - G_{n-2}$

These equations may be extended for Lesser and Mean values.

Each term is simultaneously the sum of the preceding two and the product of the previous term multiplied by Φ.

So $\Phi^4 = \Phi^2 + \Phi^3 = \Phi^2 \times \Phi^2 = \Phi^3 \times \Phi$

No other number behaves likes this, fusing addition and multiplication.

2. Golden biology

2.1. Phyllotaxis

Phyllotaxis is one of the growth functions of plants and refers to the patterns of leaf spacing on a stem. These recurring patterns have been one of the most fruitful areas for research into the role of the golden ratio in nature. Leonardo Da Vinci (1452-1519) had noticed that the spacing of leaves on plants was often spiral in arrangement. Johannes Kepler (1571-1630) later noted that the majority of wild flowers are pentagonal, and that Fibonacci numbers occur in leaf arrangement. Observation by naturalists of the spiral patterns such as florets in the head of a daisy or scales of a pinecone led to the development of the 19th century field of research called Phyllotaxis, literally 'leaf arrangement'. The Bravais brothers (1837) discovered the crystal lattice and the ideal divergence angle of phyllotaxis: $137.5^o = 360/\Phi^2$. Research has found that phyllotaxis leads to a leaf arrangement that is most effective and efficient for the plant in receiving maximum sunlight, moisture and pollination. The suggestion herein is that this is an example of aesthetics based in the efficiency of function itself.

In the foreword to their monumental treatise, *Symmetry in plants,* Jean and Barabe place the golden ratio front and center of the mystery when they write: «Daisies and sunflowers are the emblems of phyllotaxis: all the problems of phyllotaxis are summarized therein. The presence of particular numbers **(**e.g. Fibonacci numbers, an angle of 137.5^o, the golden number $\tau = (\sqrt{5}+1)/2 \approx 1.618$**)**, and forms (e.g. logarithmic spirals) in their capituli, and shoot apices, demands an explanation, and has served as a spur to the human intellect. [...] It is in phyllotaxis that symmetry in plants is most striking and puzzling» (Jean and Barabe 1998, vii).

Architect Oleg Bodnar, a Ukrainian Professor at Lvov National Academy of Arts, published his discovery of a new geometrical theory of phyllotaxis based upon hyperbolic rotation using golden hyperbolic functions. He called it *The law of spiral bio-symmetry transformation,* and discussed it in his book *The golden section and Non-Euclidean geometry in science and art* (1994). Non-Euclidean hyperbolic geometry had been used by Herman Minkowski to help visualize the curvature of space-time in Einstein's theory of Special Relativity. But Non-Euclidean hyperbolic geometry had only found application at very high speeds in outer space. Now, for the first time, the same geometry was found to be applicable throughout nature itself.

2.2. Golden heart

Russian biologist V.D. Tsvetkov published his findings on the role of the golden ratio in the cardiac activity in humans and other mammals in his 1997 book *Heart, the golden section and symmetry*. Tsvetkov found that if we take the middle blood pressure in the aorta as the measurement unit, then the systolic blood pressure approaches 0.382..., and the diastolic pressure approaches 0.618..., that is, their ratio corresponds to the golden ratio (0.618… : 0.382… = 1.618…). The golden ratio can also be observed in a cardiogram, where the comparison is made of two time intervals of different duration corresponding to the heart's systolic (t1) and diastolic (t2) activity. Tsvetkov discovered that there is an optimal (or golden) frequency for man and other mammals; here, the durations of systole, diastole and the full cardiac cycle (T) are in golden mean proportion, that is, T : t2 = t2 : t1. It means that cardiac performance in the timing cycles and blood pressure variations is optimized by the law of the golden ratio. According to this principle, nature has constructed the heart in such a way that it performs its function with minimal expenditures of energy, blood, muscle and vascular tissue. Again, another example of aesthetics being found in optimal function.

2.3. Golden division of biological cells

C.P. Spears and M. Bicknell-Johnson demonstrated that an extension of Fibonacci numbers, based on the Pascal triangle, can model the growth of biological cells. They conclude that «binary cell division is regularly asymmetric in most species. Growth by asymmetric binary division may be represented by the generalized Fibonacci equation. […] Our models, for the first time at the single cell level, provide a rational basis for the occurrence of Fibonacci and other recursive phyllotaxis and patterning in biology, founded on the occurrence of the regular asymmetry of binary division» (Spears and Bicknell-Johnson 1998).

2.4. Golden human genome

M.E.B. Yamagishi and A.I. Shimabukuro (2008, 643) found that nucleotide frequency in the human genome can be accurately approximated and predicted using Fibonacci numbers. It is interesting to note the solution was arrived at as part of an optimization problem – closely mimicking nature.

J.C. Perez (2010) discovered that codon populations in single-stranded whole human genome DNA are fractal and fine-tuned by the golden ratio or 1.618…. This discovery was found by first comparing CG major and minor codons as well as TA major and minor codons. Then comparing the CG ratios with the TA ratios produces the result of *0.2618844228* which is within thousandths of a percent of matching $\Phi^2/10 \approx 0.2618033988...$. Perez also discovered that there appears to be two binary code attractors for the human genome. The top state matches the Lesser golden ratio ($\phi = 1/\Phi \approx 0.618...$). The bottom state matches one half the Lesser golden ratio ($\phi/2 \approx 0.309...$). These two states create a self-organizing bistable binary code. Amazingly these two states are in a perfect octave of one another, the top state being exactly twice the bottom state. Here an example of beauty through musical harmonics being reflected in the function of DNA.

3. Golden chemistry

3.1. Quasicrystals

Daniel Shechtman was awarded the 2011 Nobel Prize for his discovery of a unique form of substance called quasicrystals. On April 8, 1982, while studying an aluminum and manganese compound, Shechtman observed crystals with 10 points. But this meant they had pentagonal symmetry, which of course is replete with the golden ratio. This seemed impossible according to the prevailing paradigm and established 'laws' of crystallography as to how crystals can form. Shechtman even remarked to himself in Hebrew: «Eyn chaya kazo!» («There can be no such creature!»). But there they were, though changing the paradigm would take time.

Shortly after the discovery, quasicrystals were synthesized in labs, ultimately around the world. They have regular patterns, but they never repeat. Because of their uneven structure, having no obvious cleavage planes, they are extremely strong and durable. They lack surface friction, don't react with anything, and do not oxidize or become rusty. And then in 2009 the first naturally occurring quasicrystals were discovered. They are found in some of the most durable forms of steel, and are now used, for example, in razor blades and thin steel needles for eye surgery.

Quasicrystals had been anticipated earlier by Johannes Kepler who drew quasicrystal-like patterns in *Mysterium cosmographicum.* Some even felt that Sir Roger Penrose should have been awarded the Nobel Prize because of his discovery of non-periodic pentagonal tiling patterns, which are a two-dimensional analog directly relevant to Shechtman's three-dimensional discovery. Shechtman admitted to Penrose that he may have been unconsciously influenced by the Penrose tiling discovery. But the gracious Penrose acknowledged that he may himself have been unconsciously influenced by the drawings of Kepler in his own discovery.

These discoveries were actually anticipated by early Islamic pentagonal pattern mosaics in mosques. They are evident in the Alhambra Palace in Spain and the Darb-I Imam Shrine in Iran. An analogy or link between the beauty of the quasicrystal and pentagonal architectural form.

3.2. C_{60}, the fullerene

Another golden ratio related discovery led to the 1996 Nobel Prize in chemistry for Harry Kroto of the University of Sussex, and Richard Smalley and Robert Curl of Rice University. Kroto (along with Canadian radio-astronomers) had discovered long linear carbon chains in interstellar space and was certain these long flexible molecules had been created in red giant stars rich in carbon. In 1985, using graphite heated with a laser-supersonic cluster beam, they replicated the carbon chains and also discovered a perplexing set of stable spheres, particularly in the C_{60} range and some in the C_{70} range. These spheres formed incredibly strong stable structures which they called a 'wadge' – British for 'a handful of stuff'. Smalley began calling C_{60} the 'mother wadge', and Kroto called it the 'God wadge'.

The C_{60} is a truncated icosahedron, an icosahedron in which the corners have been 'truncated' or cut off (Figure 4). It consists of 12 pentagons (like a dodecahedron) and 20 hexagons. If the edge of a truncated icosahedron is equal to one or unity, the distance across to an opposing edge is exactly 3Φ.

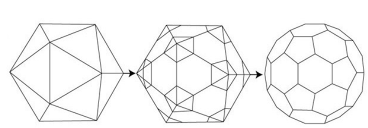


FIGURE 4: Truncation of an icosahedron

Therefore, the inner scaffolding of C_{60} is made up of three perpendicular intersecting 3Φ x 1 rectangles (Figure 5). And in C_{60} the carbon atoms are located at each of the 60 vertices (corners, Figure 6).

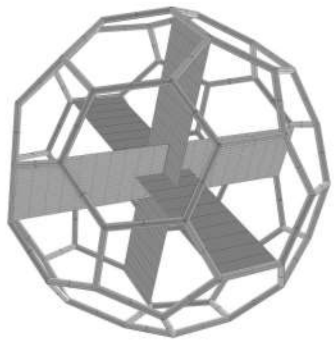


Figure 5: Truncated icosahedron with three intersecting 3Φ x 1 rectangles.

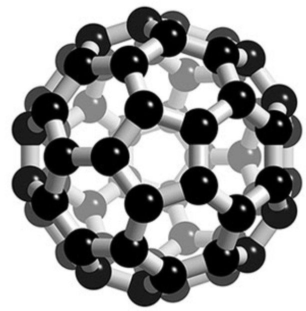


***Figure 6*:** C_{60} or a Buckyball

Smalley succeeded in building a model by interspersing pentagons amongst the hexagons. Not knowing what it was, he later reported: ‘I was ecstatic and overtaken with its beauty!’. The group presented it to Bill Veech of the Rice Mathematics Department asking him what it was. Veech responded: ‘I could explain this to you in a number of ways, but what you got there, boys, is a soccer ball’. They decided to call the C_{60} a Buckminsterfullerene or Buckyball for short. The entire group of spheres was named Fullerenes. Though not accepted until 1990 when scientists at both the Max Planck Institute for Nuclear Physics in Germany and the University of Arizona succeeded in synthesizing a sufficient amount of C_{60} to study its structure. In 1992 C_{60} was found in Russia in a family of minerals called Shungites. Lastly huge fullerenes have been discovered made up of hundreds and sometimes thousands of atoms, yet still maintaining the «same beautiful latticework shells» (American Chemical Society 2010).

3.3. Buckyballs in outer space

In 2010 NASA’s orbiting Spitzer infrared telescope recorded Buckyballs, the largest molecules ever found in space, in the nebula around a distant, white dwarf star. Jan Cami reported: ‘When we saw these whopping spectral signatures, we knew immediately that we were looking at one of the most sought-after molecules’. Bernard H. Foing responded that he and P. Ehrenfreund: ‘measured previously [in 1994] the spectral fingerprint signature of buckyballs in many directions in the galaxy. […] This C_{60+} feature has been observed in many lines of sight and seems ubiquitous in the interstellar medium'.

3.4. *Fibonacci periodic table*

Recently, Ukrainian researcher Sergey Jakushko analyzed Mendeleev's Periodic System of elements in terms of Fibonacci numbers (Jakushko 2010). If the atomic mass of each element in a period is divided by the atomic mass of the last element in the period, i.e. a noble gas, the results can be graphed thereby obtaining an average line for the period. Performing this for each period allows for a comparison of the slopes of each average line. It turns out that the slopes, starting with the first period up to the last period, change by the following law:

$$\frac{1}{1}, \frac{1}{1}, \frac{1}{2}, \frac{1}{3}, \frac{1}{5}, \frac{1}{8}, \frac{1}{13}$$

This numerical sequence is simply the inverse of the Fibonacci numbers: 1, 1, 2, 3, 5, 8, 13…. Thus, Jakushko uncovered a new Fibonacci regularity underlying the Periodic Table of Elements, linking it to the aesthetics of the golden ratio as expressed in nature.

4. Golden physics

4.1. Nested vibration, chaos border and winding number

Mohamed El Naschie recognized that because the golden ratio is the most unique of all constants, being the simplest continued fraction (Figure 1), simplest nested radical (Figure 2), and the most irrational of all irrational numbers, it is the primary candidate to give stability through what is called a 'nested vibration'.

El Naschie wrote: «It is the simplest realistic unit from which a Hamiltonian dynamics can start developing a highly complex structure, a so-called *nested vibration*». And the chaos border between order and chaos, called «the KAM Theorem (after Kolmogorov, Arnold and Moser), asserts that the most stable periodic orbit is that which has an irrational ratio of resonance frequencies. Since the Golden Mean is the most irrational number, the corresponding orbit is the most stable orbit». And «in the view of string theory, particles are vibrating strings. Therefore, to observe a particle, the corresponding vibration must be stable and that is only possible in the [aforementioned] KAM interpretation [known as the VAK Cantorian theory of vacuum fluctuation]… *when the winding number corresponding to this dynamics is equal to the Golden Mean!*» (quoted in Olsen 2006, 57).

CURRENT & CONSTITUENT QUARK MASS AS FUNCTIONS OF Φ AND 1/Φ.

Quark Flavor	*Current Mass (MeV)*	*Constituent Mass (MeV)*
Up	$2\,\Phi^2 = 5.236\ldots$	$80\,\Phi^3 = 338.885\ldots$
Down	$2\,\Phi^3 = 8.472\ldots$	$80\,\Phi^3 = 338.885\ldots$
Strange	$10\,\Phi^6 = 179.442\ldots$	$10\,\Phi^8 = 469.787\ldots$
Charm	$300\,\Phi^3 = 1{,}270.82\ldots$	$20\,\Phi^9 = 1{,}520.263\ldots$
Beauty (Bottom)	$10^3\,\Phi^3 = 4{,}236.067\ldots$	$100\,\Phi^8 = 4{,}697.871\ldots$
Truth (Top)	$10^4\Phi^3 = 42{,}360.679\ldots$	$10^4\Phi^6 = 179{,}442.719\ldots$

In the table right, notice the close agreement between the theoretical and the experimental values, and the interesting presence of the 5/2 phyllotaxis and Lucas 7/4 ratios. The E^∞ values of the fundamental constituents involved below are as follows: $\bar{\alpha}_0 = 20\Phi^4 = 137.0820\ldots$ is the inverse Sommerfield electro-magnetic fine structure coupling constant. $\kappa = \Phi^{-3}(1-\Phi^{-3}) = 0.18033988\ldots$ and $\kappa_0 = \Phi^{-5}(1-\Phi^{-5}) = 0.08203925\ldots$ are two Φ-based constants. $\bar{\alpha}_g = 10\Phi^3 = 42.3606797\ldots$ is the theoretical value of the coupling constant $\bar{\alpha}_0$ at the point where three non-gravitational forces intersect. $\bar{\alpha}_{gs} = \bar{\alpha}_g/\Phi = 26.18033988\ldots = (10\Phi^3)/\Phi = 10\Phi^2$. This is the inverse coupling constant at the super symmetric unification of all fundamental forces taking place at the Planck length of 10^{-33} cm.

SUBATOMIC PARTICLE MASS AS A FUNCTION OF Φ AND 1/Φ.

subatomic particle	*theoretical mass (MeV)*	*experimental value (MeV)*
e (electron)	$\sqrt{\bar{\alpha}_{gs}}/10 = \sqrt{(10\,\Phi^2)}/10 = 0.51166\ldots$	0.511
n (proton)	$\bar{\alpha}_0{}^2/20 = (20\,\Phi^4)^2/20 = 939.574\ldots$	939.563
P (proton)	$(\bar{\alpha}_0 - \kappa_0)^2/20 = 137^2/20 = 938.45\ldots$	938.27231
$\Pi^\pm$ (Π meson)	$\bar{\alpha}_0 + (5/2) = 139.5820\ldots$	139.57
Π^0	$\bar{\alpha}_0 - (5/2) = 134.5820\ldots$	134.98
Ω^-	$10[\bar{\alpha}_0 + (49/\Phi)] = 1{,}673.657\ldots$	1,672.43
Exi^-	$10[\bar{\alpha}_0 - (8/\Phi)] = 1{,}321.377\ldots$	1,321.32
Exi^0	$10[\bar{\alpha}_0 - (9/\Phi)] = 1{,}315.197\ldots$	1,314.9
μ (muon)	$\sqrt{(1000\,\Phi^5)} = 105.309$ or $(20+\kappa)(5+\Phi^{-3}) = 105.665\ldots$	105.65839
η	$(4\,\bar{\alpha}_{gs})^2/20 = (40\,\Phi^2)^2/20 = 548.328\ldots = m_\eta$	548.8
η'	$(7/4)\,m_\eta = (7/80)(4\,\bar{\alpha}_{gs})^2 = 959.5742755\ldots$	957.5

***FIGURE 7*:** Quark and subatomic particle masses as functions of Φ and ϕ (Olsen 2006, 57)

4.2. Fine structure constant, quark masses, "harmonic musical ladder"

El Naschie discovered that the standard model of particle physics, when viewed through the eyes of E-Infinity Theory, appears to be 'a cosmic symphony' with incredible states of harmonic resonance. In effect, he may have found the Pythagorean Music of the Spheres present in the world of physics. And from his E-Infinity Theory he deduced the fine structure constant of nature ($20\Phi^4 = 137.0820\ldots$), the masses of quarks – the most elementary known constituents of matter, as well as the masses of the electron, proton, neutron and the other sub-atomic particles! El Naschie stated that: «the quark masses are in excellent agreement with the majority of the scarce and difficult to obtain data about the mass of quarks. It takes only one look at these values for anyone to realize that they form a *harmonic musical* *ladder*!» (Olsen 2006, 57). This raises a very interesting issue regarding the Higgs Boson which is said to give quarks their masses. This is a direct example of aesthetics resulting from the golden modular of nature itself.

4.3. Entanglement, nonlocality and ϕ^5

In 1993, Lucien Hardy wrote a paper titled *Nonlocality for two particles without inequalities*. This was a masterful piece of work, a thought experiment, in which Hardy demonstrated that entanglement occurs with the probability of 9.017%. Unfortunately Hardy rounded off the actual calculation, and as a result, at least initially, El Naschie and Penrose (two of the few in the world who would have recognized it) missed it. The result suggests that in roughly 1 out of 11, or 9 out of 100 trials, entanglement of two particles will be observed. This also is tantamount to 9 instances in 100 trials where a quantum particle will be in two different locations at exactly the same time!

Eventually El Naschie realized that Hardy had rounded off his result. The actual calculation was 0.09169945… or written as a percentage, should be 9.0169945…%. Hardy apparently did not realize it, but he had discovered that entanglement occurs at the 'Lesser' golden ratio, ϕ, raised to the 5th power, i.e. $\phi^5 \approx (0.6180339...)^5 \approx 0.09169945\ldots$. El Naschie found that Hardy's result was perfectly consistent with what he derived through E^∞ Theory employing 'fractal' Cantor sets.

Thus, even the quantum mystery of entanglement is guided by the aesthetics of the golden ratio.

4.4. Solving quantum paradoxes

The great insight of El Naschie was the realization that fractal Cantor sets (driven by the golden ratio) allow one to not only capture the fractal nature of quantum theory, but resolve its difficult paradoxes, including the wave-particle duality paradox. When using Cantor sets, the quantum particle state is a 'zero measure Cantor set' of (0;ϕ) equal to 0.6180339… and the quantum wave state is the 'empty measure Cantor set' of (-1;ϕ^2) equal to 0.3819660…. The wave and particle are separated by (i.e. related through) what is beginning to appear to be the Modular of Nature itself: $\Phi \approx$ 1.6180339…. Hence, multiply a wave by Φ and it transforms into a particle. Divide a particle by Φ and it transforms into a wave. This in fact mimics (or is mimicked by) the interplay of adjacent Fibonacci numbers in nature. Multiply a Fibonacci number by the Modular $\Phi \approx 1.6180339...$ and you will get an approximation to the next Fibonacci number. Of course, divide a Fibonacci number by the Modular Φ and you will get an approximation to the previous Fibonacci number.

What is lurking behind the scenes here, and most importantly for our deeper interests, is the fact that these 'fractal Cantor sets' – guided by the golden ratio – allow for nonlocality. When there is no spatial or temporal separation at the most fundamental level, as Bohm and others had always maintained with quantum mechanics, there is immediate contact. This has a tremendous bearing on all issues related to consciousness research, morphic resonance and PSI phenomena.

4.5. Dark energy

El Naschie concludes that the energy given by Einstein's famous formula $E = mc^2$ consists of two parts. «The first part is the positive energy of the quantum particle modeled by the topology of the zero set [$\phi \approx 0.618...$]. The second part is the absolute value of the negative energy of the quantum Schrödinger wave modeled by the topology of the empty set [$\phi^2 \approx 0.381...$]. We reason that the latter is nothing else but the so-called missing dark energy [inclusive of dark matter] of the universe which accounts for 94.45% of the total energy, in full agreement with the WMAP and Supernova cosmic measurement which was awarded the 2011 Nobel Prize in physics. The dark energy of the quantum wave cannot be detected in the normal way because measurement collapses the quantum wave» (El Naschie 2013, 591).

4.6. Quantum mechanics and golden symmetry

On January 8, 2010, researchers in Germany (Helmhotz-Zentrum Berlin) working with colleagues in England (Oxford and Bristol Universities, and the Rutherford Appleton Laboratory) reported that they had discovered the golden ratio in quantum mechanics. Applying a magnetic field to cobalt niobate ($CoNb_2O_6$), their press release stated that they: «have for the first time observed a nanoscale [golden ratio] symmetry hidden in solid state matter. […] By tuning the system and artificially introducing more quantum uncertainty the researchers observed that the chain of atoms acts like a nanoscale guitar string». Dr. Radu Coldea of Oxford University, principal author of the paper in the journal «Science», later explained: «The tension comes from the interaction between spins causing them to magnetically resonate. For these interactions we found a series (scale) of resonant notes: The first two notes show a perfect relationship with each other. Their frequencies (pitch) are in the ratio of 1.618…, which is the golden ratio famous from art and architecture. […] It reflects a beautiful property of the quantum system – a hidden symmetry. Actually quite a special one called E8 by mathematicians, and this is its first observation in a material» (Coldea 2010).

5. Consciousness

In 1995, University of Oxford mathematics professor Sir Roger Penrose, and University of Arizona anesthesiology professor Stuart Hameroff, in a paper titled *Quantum computing in microtubules: self-collapse as a possible mechanism for consciousness*, proposed that consciousness can be explained as quantum computations orchestrated through groups of microtubules in the neurons of the brain. They argued that the microtubules in a quantum coherent state could go through *objective reduction* or what in quantum physics is called the collapse of the wave function. In quantum theory, probability waves can be held in superposition, being in two places at once. When observation occurs, the wave can collapse into an objective actuality. This is consistent with the present author's position that the ϕ^2 wave collapses into its corresponding ϕ particle as expressed in Section 4.4.

Microtubules are self-assembling polymers (i.e. large molecules or macromolecules composed of repeating structural units) located in the cytoskeleton within neurons (and all cells). They are hollow cylinders composed of 13 linear tubulin chains (protofilaments) that align side-by-side, forming spiral patterns that are similar to a pinecone or sunflower, with 8 spirals winding in one direction and 5 spirals in the opposite direction (Figure 8).

Occasionally double-microtubules form with 21 spirals, 13 spiraling in one direction and 8 in the other! Thus, the double microtubule has 'additively and geometrically' moved up what one might term a 'golden or Fibonacci octave' so to speak. Again, the aesthetic principle is manifest in the microtubule structure itself.

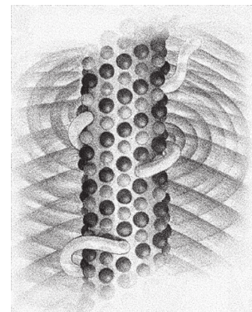


FIGURE 8: Microtubule

Early on in his book, *Shadows of the mind, a search for the missing science of consciousness,* Penrose raised the question (perhaps somewhat rhetorically): «Why do Fibonacci numbers arise in microtubule structure?» (Penrose and Hameroff 1994, 362). Seventeen years later Penrose and Hameroff wrote that the «multiple winding patterns […] matching the Fibonacci series found widely in nature and possessing a helical symmetry, [are] suggestively sympathetic to large-scale quantum processes» (Penrose and Hameroff 2011, 226).

As part of the cytoskeleton, the microtubules establish cell shape, direct growth, and organize cellular functions, «defining cell architecture like girders and beams in a building» (Penrose and Hameroff 2011, 226). But their lattice structure can be compared to computational systems. Penrose and Hameroff see them as *biomolecular quantum computers*. This means there can be entanglement, superposition (being in two places at once), and immediate 'nonlocal connection' even when appearing 'locally' separated (see Section 4.3).

And where quantum connections occur, the atoms can become *quantum coherent*. Quantum 'in-phase states' like this occur, for example, when the atoms of helium-4 are cooled to near Absolute Zero and become highly coherent, leading to superfluidity. Analogous phenomena also occur in the coherent light of lasers and in superconductivity. The important point is that this creates a *Bose-Einstein condensate* where the atoms are said to «resonate in-phase within a common Schrodinger wave function» (Merrick 2009, 196). Is there an underlying 'golden in-phase resonance' at work here?

A serious question arose regarding the Penrose-Hameroff microtubule/quantum computer hypothesis. Provocative research in 2003 began to demonstrate that quantum coherence occurs even in warm biological systems, including 'bird brain' navigation, DNA, protein folding, biological water and microtubules. In fact Penrose and

Hameroff have given this golden ratio driven resonance greater clarity, stating: «Moreover, geometrical resonances in microtubules, e.g. following helical pathways of Fibonacci geometry are suggested to enable topological quantum computing and error correction, avoiding decoherence perhaps effectively indefinitely as in a superconductor» (Penrose and Hameroff 2011, 242).

Clathrins, located at the tips of microtubules in the axon's synaptic boutons, are buckyball shaped proteins (Figures 8 and 9) that selectively sort cargo at the cell membranes. As truncated icosahedra they have internal rectangles constructed in the ratio $3\Phi:1$ (see Figure 2). During mitosis the clathrins bind directly to the microtubules (or microtubule-associated proteins called MAPS). But most importantly, together with microtubules the clathrins regulate synaptic activity. The suggestion here is that their 'golden in-phase resonance' and attendant aesthetics may hold a central key to the mystery of consciousness itself! Hence, beauty, function and illumination may be intimately tied together.

***Figure 9*: Clathrin**

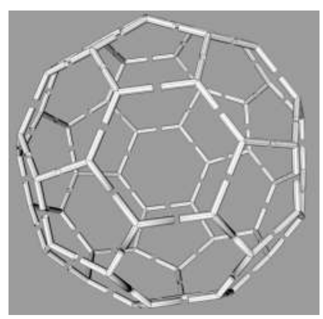


***Figure 10*: Clathrin structure**

6. Conclusion

The evidence presented here for the pervasiveness of the golden ratio throughout the sciences merely scratches the surface and one could easily cite more instances of its occurrence. The potential applications for the golden ratio stretch from the macrocosmic down to the microcosmic scale, appearing to have scale independent relevance to everything in between. All of this scientific evidence for the role of the golden ratio throughout nature and the cosmos provides a very strong argument for the scientific foundation of aesthetics in the world. It should not be surprising that that which runs most perfectly is the most beautiful, and the most beautiful may be involved in illumination.