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Occult Arithmetic: Music, Mathematics & Mysticism

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Preface

The paper was written following a thought-provoking weekend at the SkyWay '09 festival of light in Torun, Poland. Robert Priddey and I were invited to present alongside other academics and artists at a seminar devoted to collaborations between science and art. Simeon Nelson's involvement in this event spawned a firm friendship and exchange of ideas. They hoped to run a symposium together celebrating and encouraging collaboration between science and art; *Ways of Knowing* was the culmination of this idea. Robert died in February 2010 at the age of 34; this highly personal, emotive paper was the last he wrote. His enthusiasm for, and vast abundance of knowledge on, so many subjects, and how they can be brought together, will never cease to inspire me. It is an honour to have had him as my doctoral supervisor. Examples of his artwork, musical compositions, poetry and other words can be found at http://robertpriddey.com/ - Alice Williamson.

Abstract

The ancient Pythagorean sect bequeathed an abstract concept of music – later known as *musica universalis* – music as pattern, flow, a direct embodiment of the fundamental processes and forms underlying reality, all beginning with the connection between harmonious musical intervals and simple ratios. Through the centuries, this beguiling notion continued to re-emerge; amplified, elaborated and reinterpreted in the work of the most prominent philosophers and physicists. To what extent could it still be said to hold? In what way can it stand as an archetype for the interaction between art and science? This paper seeks to answer these questions. Circling around the statement of Liebniz that music is an exercise of "occult arithmetic", it considers – through a historically-driven speculation from Pythagoras to Schopenhauer – music's capacity to enlighten us, and how it can correspond to concepts of order and chaos, intuition, creativity and metaphysical transcendence. Further questions are ultimately raised: what does art represent as opposed to scientific enquiry? How can science and art complement one another?

"Musica Exercitium Est Arithmeticae Occultum Nescientis Se Numerare Animi"
(Gottfried Leibniz)

Music, most of all the arts, is perennially dubbed mathematical and abstract. This tradition goes back at least as far as Plato, who in the *Republic* chides acoustic investigators for rating ears above intellect. They torture strings, he ridicules, and beat them on the rack as they pluck them under tension; wringing confessions from just them as Athenian jurisprudence decreed for the interrogation of a slave (Plato *The Republic*, VII 531b: Bloom 1968, 209). It all seems like sound empirical science to us, but for Plato, the testimony of experience was worth no more than the flimsy deposition of a slave. He levels the same charge against astronomers: "There's nothing more beautiful," he admits, "than these ornaments in the sky" but, for being visible, they should be regarded inferior to pure patterns "in the realm of number" (Plato *The Republic*, VII 529).

In listing in the same breath the sins of acoustic experimenters and the sins of astronomers, Plato is alluding to the philosophical tradition said to have been established by Pythagoras of Samos in the 6th century BCE. Pythagoras is best remembered in the popular mind as a mathematician – he of the square on the hypotenuse. Indeed, Aristotle praised Pythagoras and his followers as "the first to take up mathematics" (Aristotle, *Metaphysics* A 5 985b 23: Barnes 1984, 1559), because they pursued general laws (such as $a^2 + b^2 = c^2$) rather than specific instances (such as $3^2 + 4^2 = 5^2, 5^2 + 12^2 = 13^2$, $8^2 + 15^2 = 17^2$, etc.)[1] To the ancients, though, he was also revered as the founder of a religious sect, in whose creed mathematics, music, and astronomy were sacrosanct.

"All Is Number" – The Pythagoreans

The Pythagorean brotherhood[2] flourished around the ancient Mediterranean from around the 6th century BCE. It seems to have been part secretive philosophical school and part mystery religion in the line of the Dionysian and Orphic cults. The initiate aspired to a state of rapture, *ekstasis* (whence "ecstasy"), in which one attains mystical union with the divine – *homoiōsis theō*. The Bacchics' sacraments were wine and other intoxicants; the Pythagoreans' entheogen, much more ascetically, was *philosophy*. According to tradition, Pythagoras is said to have invented the word *philosophia*, seen originally not as an exclusively intellectual, but as a ritualistic exercise. And the mystical insight into reality that it afforded was the Pythagoreans' chief doctrine, a radical, mathematical ontology: *all is number*.

This revolutionary metaphysic could be said to have kick-started our modern picture of physics as inherently mathematical, but it was derived from a *musical* discovery, said to have been made by the founder, Pythagoras, himself: that intervals considered harmonious

are governed by simple ratios of integers. Greek music, at least in Classical times, would have sounded alien to our ears; both Plato and Aristotle would have considered our diatonic music loose and immoral, preferring excruciating microtonal tunings. Nevertheless, all scales had a set of invariant intervals: the octave, the perfect fifth and the perfect fourth. It was these intervals that the Greek thought harmonious, and it was these intervals to which the Pythagoreans ascribed ratios, namely, 2:1, 3:2 and 4:3 respectively; probably initially referring to lengths of plucked strings, though now we know these numbers represent relative frequencies of acoustic vibrations.

If something seemingly so subjective as musical harmony is governed by the first few integers, then why not everything else? This was indeed the Pythagorean view: *all is number*. Not merely “all is based on number” or “all can be described by number”, but all *is*, deep down, in an ontological sense, number. How could this work? Well, one primitive Pythagorean model of particle physics declares that matter (in this case the five elements) is made out of fundamental geometrical figures: the five Platonic solids.[3]

To the Greeks, nothing exhibited order and regularity as clearly as the starry heavens: the diurnal rotation of the sky, the unending annual progression of the sun. Above all, the Pythagoreans thought that the planets wheel about their orbits according to those same ratios that rule musical harmony. As they soar around the sky, they would thus choir consonantly like sirens or angels. The Pythagorean universe is one above all governed by order. They were the first to apply the Greek word for “order”, *kosmos*, to refer to the whole universe as a structured system. Furthermore, it is a *harmonia*, and, like musical harmony, can be appreciated and understood by the divine part of our own nature, and yield an explanation or *logos* through the exercise of reason.

Perhaps embarrassed by its odder superstitions, the religious element in Pythagoreanism was too often glossed over by later commentators in favour of its purely rational doctrines. But in our survey of art and science it is too delicious to overlook that, at the origin of the Western scientific world-view, the rational walked hand-in-hand with the irrational. Well – not *irrational* so much as *non-rational* or even *supra-rational*, in the sense of insights and convictions that, though held deeply and seriously, cannot be communicated through precepts nor justified through reason.

Instead, it draws on myths and metaphors. There is an interesting soteriological parable – almost like a Zen *kōan* – concerning Pythagoras himself, which I think contains the key to decrypting the cult’s secret core symbolism. According to legend, the Master was said to have been able to *hear* the music of the spheres. We do not; well, actually we do, it is just that we do not notice that we do because we have always done so and never thought to question it. So distracted and corrupted by everyday things are we that we do not see the

most profound and obvious truth though it lies forever beneath our nose: the Music of the Spheres is perhaps a metaphor for the greatest of all mysteries, that of existence itself (is this the “Silence of the Druids” that Charles Ives represented in his chamber work *The Unanswered Question*?) (Ives 1953).

Through philosophy one may aspire to the saintliness that permits one, like Pythagoras, to perceive the fundamental nature of reality, the *cosmos*, and this can be achieved in two ways. The first, intellectual, through the exercise of abstract mathematics and reasoning in search of an explanation, or *logos*. Plato, as we have seen, thought this sufficient: there is no need to experience the phenomenological world in order to understand the higher realm of abstract “Forms”. But is a rational account enough? Pythagoras *heard* the music, remember! The second, non-rational: intuitive – visceral, ecstatic, even – the experience of music leading to mystical communion with the nature of reality.

This Music of the Spheres, taken as a literal model of the universe, though fanciful, proved irresistible to the greatest physicists – Ptolemy, Copernicus, Kepler and Newton, all of whom tried to preserve it in some way.[4] Their attempts all fell by the wayside. But on a metaphorical or poetic level it still stands as an archetype of science/art discourse: science, at its birth in the 6th Century Greek colonies, was made vivid and personal and piquant through art.

The Dynamics of Music

A well-known line of Gottfried Leibniz provides the title for this essay. Leibniz was corresponding with his disciple Christian Wolff:[5] “*musica exercitium est arithmeticae occultum nescientis se numerare animi*” (“music is the hidden arithmetical exercise of a mind unconscious that it calculates”) (Leibniz 1712, 199).

Music is arithmetic: Plato would have no dispute with that. But, crucially, it is *hidden* arithmetic. Listening to music, the conscious mind does not explicitly count and divide and compare ratios and derive intellectual pleasure thereof. Appreciation of the patterns and forms of music is only partly rational; for the most part, it is unconscious, emotional and *intuitive*. One knows without knowing one knows. Most listeners will recall the salient features of an entity as complex as a Beethoven symphony after only one or two hearings. Memorising the phone book or the decimal expansion of *pi* would be, in distinction, dishearteningly effortful. While Beethoven’s notes rendered into pure number would undoubtedly prove more consistently patterned and memorable than the phone book, I for one prefer not to experience the *Eroica* that way. Music consists of emotionally significant content organised in an intuitively amenable form.

Although Leibniz was speaking of the static numerology of harmony – the consonant bliss of chords governed by the Pythagorean ratios[6] – his remark might just as well have encompassed the time-dependent patterns and forms of music, music as change, music as motion, music in a dynamical sense. In Leibniz' day, dynamics as a science was yet in its infancy. We are used to the post-Newtonian world in which maths can send a man to the Moon, but through the 17th Century it yet aspired to mathematical rigour. Leibniz himself had had a leading hand in its rearing, having developed Descartes' vague notion of *vis viva*, "living force", into the mathematically concrete concept that we now call kinetic energy.[7] Ultimately, the rise of Newtonian dynamics made clear that the motions and interactions of bodies was equally as mathematical a matter as Pythagoras' ratios.

Leibniz' intuition must have led him to suspect that the motions of bodies followed mathematical laws. It was left to his rational mind to derive such a law by contemplating idealised configurations, contrived to make clear new lines of reasoning – a "thought experiment" as such contemplation is termed. Perhaps, given that the Pythagorean ratios governed harmony, the science of musical statics, there were equally laws of musical dynamics that were yet to be discovered?

The Pythagorean basis of harmony confers at least some level of objectivity, consonance and dissonance providing fields of force directing the motion of music. And we can indeed speak of "motion" in music, for music's most salient characteristic is that it takes place in time. Musical elements and structures subsist in time. It is their evolution that we find fascinating, and the degree to which this development is conditioned by the innate potential of elements and their interaction with contrasting ideas. Dynamical dissonance embraces a much wider concept than disharmony: interruption of rhythmic pattern, change of key, disruption of mode, asymmetries and broken progressions, knock the system out of equilibrium. The music, to recover its balance, wanders through even more remote regions before it winds its way back to its state of rest in order and consonance. It is dissonance that drives the music forward; perfect harmony is musically inert, incapable of further development.

I do not mean this analogy to be taken too formally. Music cannot be modelled as a literal physical theory. But on some underlying level, the same cognitive resources are harnessed when we observe complex dynamical systems as when we watch tendrils of ink curling through water, debris dancing in dust devils, or as when we hear the swirling arabesques of a Chopin *Étude*.

Music is like physics, but physics in a sense closer to the Aristotelian word *physis* – the propensities of objects to grow, change, move according to their own nature. This sense

is as much organic and biological as it is mechanical, as much teleological as it is deterministic.

Above all it is *intuitive*, but this is not to imply intellectual inferiority. Musicologists praise the “logic” of a Haydn quartet or a Beethoven sonata. Sibelius famously told Mahler that the essence of the symphony lay in its “profound logic”.[8] So – “profound logic”; “hidden arithmetic”: not in the sense of simplistic algorithm or crass numerology, but a subtle, poetic rigour concealing its secrets beneath the surface. To bowdlerise Blaise Pascal, “the Art has its reasons, which Reason doth not know”.[9] When the organisation becomes too explicit, too trite, art falls apart. The subtle nebulae of Rothko’s blocks, the whorls of a Pollock drip painting, the sonic torrent of a Nancarrow Player Piano Study are too overwhelming for my intellect to absorb; yet my intuition delights in their rich textures, and I want to believe they are the product of an order too subtle or complex for my rational mind to fathom.

Unruly Rules; Inklings & Intimations

It is interesting that Leibniz, the champion of the “occult arithmetic” of music as an intuitive form of calculation, developed a distaste for the abstraction of science, railing against those “…incomplete and abstract concepts, which thought supports but which nature does not know…these are nothing but the incomplete thoughts of philosophers who do not sufficiently look into the natures of things” (Leibniz 1703, 252-258).

Leibniz, one of the foremost mathematical physicists of the Enlightenment, knew that the abstraction of physics – that remarkable intellectual triumph of his era – was not enough. How, after all, could it be otherwise? We live in a world of such complexity that classical physical models were necessarily idealised approximations determined under carefully isolated, close-to-equilibrium conditions. They seem laboured and unintuitive because in an environment teeming with complexity, they make bad cognitive templates for any efficient, fast-reacting creature. An intelligent organism that made extrapolations about its environment by solving differential equations from the bottom up would make for very bad design sense. In a desperate, tight, fight-or-flight situation, we don’t have time to solve differential equations. Neither do we have the luxury of taking measurements precise enough to beat the notorious sensitive dependence on initial conditions characteristic of non-linear systems.[10]

That is not what we do. Fortunately, the physics of non-linear systems, complex systems and – Chaos Theory in the popular parlance – offers clues as to what strategy the “blind watchmaker” of evolution might have adopted instead.

That there can be a science of complexity at all is remarkable, no less that we find the objects of that science – strange attractors and fractals – intriguing and beautiful, and

that intelligent life can flourish in a world.[11] It is possible because systems that are non-linear, far from equilibrium, or that possess many degrees of freedom, exhibit striking emergent order on high levels, patterns which exhibit universal properties independent of their method of production. The burgeoning science of pattern formation shows us that simple low-level rules can give rise to remarkably rich phenomena, preserving qualitative and quantitative similarities across a wide range of physical, chemical, biological and computational systems.

In Karl Popper’s words, “all clouds are clocks, even the most cloudy of clouds” (Popper 1966). But you’re not going to get very far very fast if you persist in modelling each and every water molecule in a cumulonimbus. No, but there is something irreducibly “cloudlike” about our perception of clouds that defies clocklike analysis, yet manages to follow into its own set of amorphous natural laws couched in terms of ineffable cloud-essence. They seem to follow a set of unruly rules. So perhaps it is truer, from the point of view of human intuition, to say that “all clocks are clouds, even the clockiest of clocks.” Clocks are ideal abstractions; clouds are the bread and butter of the complex and messy world that we inhabit. A perceptual system attuned to the high-level, universal, laws that emerge from complex systems would prove adaptable to a remarkably wide range of phenomena.

Music (and art in general) is perhaps an echo, isolated and distilled, of such a perceptual capacity, an exercise not quite in arithmetic, but in a sort of “folk physics”, based on qualitative, intuitive inklings of emergent properties which we use to navigate through a seemingly ruly-yet-unruly world. All we need to know are the unruly “cloud” rules; we neither need to know the underlying ruly “clockwork” rules, nor can we derive them, thanks to the sting-in-the-tail of universality.[12] Still, we have faith that there is an order. That faith sets the creative artistic flame alight, no less the scientific curiosity tingling. In art, we aim to transpose the high-level pattern into new media, like paint on canvas or notes on strummed strings, with rules each of their own; to transpose and to amplify and to spin into new creations. In science, we wish to isolate and reduce and ascertain the rules that give rise to the patterns, confirming our hunch that such rules exist, and that they might reveal some fundamental new law of nature. Art sets patterns free, to do as they will, without having to explain themselves; science pins them down.

When we step back from the canvas or leave the concert hall and encounter textures in the real world – the web-like veins of marble, the grain of wood – we carry over these intuitions for forms and structures, patterns and processes that have been honed through our contact with art. We start to see van Gogh’s swirling skies, hear Messiaen’s pungent harmonies in birdsong. The role of art is to disclose, amplify and present back to the world

the latent order that we perceive within it. It makes concrete our grasp of pattern, process and form that observation of nature engenders within us. When we sense an order that we cannot quite grasp consciously, it sets our imagination tingling: "The imminence of a revelation that does not occur," Jorge Luis Borges once wrote, "is, perhaps, the aesthetic phenomenon" (Borges1964, 223). In unsatisfied curiosity lies endless creative potential.

Music as Metaphysical Abstraction

But there are those that would consider this speculative union between music and physics too easy and banal and incapable of doing justice to the greatest art. Have we not neglected the mystical, metaphysical element of Pythagoreanism? Physical theories come and go – yesterday it was Newton, the day before Pythagoras, now it is chaos theory; but tomorrow? A great work of art is eternal, and must transcend the theory of the age if it is to survive. It is not physical, but metaphysical.

The philosopher who, after Pythagoras, is renowned for elevating music to the level of metaphysics is Schopenhauer. Paraphrasing Leibniz, he remarked that: "music is the hidden metaphysical exercise of a mind unconscious that it philosophises" (Schopenhauer (1819) 1910, 333). The pleasure of music is not merely the intellectual satisfaction of arithmetic, of "making a sum come out right", as he says, but:

> We must attribute to music a far more serious and deep significance, connected with the inmost nature of the world, and our own self. Music is as direct an objectification of the whole Will as the world itself. That is why the effect of music is so much more powerful and penetrating than that of the other arts; for they speak only of shadows, but music speaks of reality itself.

In other respects, his was a most un-Pythagorean system, in which the ultimate nature of reality, which he called the Will, was a chaos, not a cosmos. Like Kant's Things-in-Themselves, the Will remains hidden and all we see are distorted appearances, refracted through the flawed prism of consciousness. But unlike Kant, Schopenhauer granted that, through art, and through music in particular, the "inmost nature of the world" was ultimately accessible to us. Music speaks directly in terms of metaphysical fundamentals.

The 6th century philosopher Boethius distinguished between ordinary audible music, *musica instrumentalis*, and the abstract music of the cosmos, *musica universalis*. Music is here considered, not so much a representation of the world in the medium of sound, but in a metaphysically prior position: the transcendent order and process from which both audible music and the physical universe arise.

Paradoxically, it is only through the experience of *musica instrumentalis* that we approach *musica universalis*. Art affords a glimpse of eternal, universal truths, but it does so through being embodied in finite particulars, experienced by corrupt and imperfect beings. When Shakespeare, in *The Merchant of Venice*, says of the Music of the Spheres that "Such harmony is in immortal souls, / But whilst this muddy vesture of decay / Doth grossly close it in, we cannot hear it" (Shakespeare *The Merchant of Venice* V.i.63). He is wrong; art *ennobles* "this muddy vesture of decay".

Science is concerned with the general properties of things; but it is their particular essences that we experience most vividly. The wonder of art is that it makes intuitively explicit the universal laws and underlying forms immanent within these particular, contingent essences. Oilpaint, hogbristle brush, canvas; gut string, hair bow, spruce soundboard: these are not merely the means of representing; their homespun, down-to-earth characteristics inform the very essence of their purpose. Art aspires to spirit by revelling in its embodiment in flesh.

It's not so much that art *represents* any particular philosophy; art *is* philosophy. Art-philosophy is mythology in the widest and the best sense – an exercise in fantasy that takes one's entire belief system into its purview. By manipulating, arranging, editing objects in the world, the artist selects the configuration that articulates most clearly to the viewer his or her belief; a belief that does not suffer the theory-ladenness of scientific models because – like the best scientific experiments[13] – it states its case directly in terms of real objects rather than derived concepts.

Anarchist historian and art writer Herbert Read summed things up concisely: "Art becomes an intuitive means, as exact as mathematics, for representing the fundamental characteristics of the cosmos" (Read 1959). Maybe not so much as representing – ultimate truths are too vast and too subtle for that – but conditioning us to glimpse the deep underlying principles that bind all things.

Summary

The greatest gift science has to give is a sense of awe and wonder. When I observe the planet Jupiter through a telescope or watch birds flocking I still, after so many years, feel an overwhelming rush of emotion that is almost religious, an inexplicable sense of coming into contact with the mystery of Being. This must be close to the Orphic experience of ecstasy – a feeling so intense, so shocking in its profundity that one loses oneself.

It must, too, lie behind the Pythagoreans' reverence for number and for the Music of the Spheres. It is life-changing; surely as much for the ancient Greeks as for us. Unfortunately it has little to do with modern academic science, procedural, humdrum, metric-

obsessed, grant-starved and backbiting. I know how Whitman felt when he evacuated an astronomy lecture “soon unaccountable… tired and sick” (Whitman 1900) and went to gaze dumbstruck at the stars (I dare say, I’ve given lectures myself like that). It needn’t be like this: we must simply never forget what is at stake, the profoundest of human emotions, more important than mere cleverness. Art can do this too – to name a couple of personal choices, the conclusion of Sibelius’ *Seventh Symphony*, or Cézanne’s *Grandes Baigneuses*.

This subjective, Orphic art, in dialogue with science, can satisfy our craving for meaning; amplify the numinous and sublime in nature; intimate the infinite; and hint, through our particular, subjective, finite interaction with the world, at nature’s universal law. “Science, unadulterated,” wrote Bertrand Russell, “is not satisfying; men need also passion and art and religion” (Russell 1945, 26). After all the numbers have been crunched, lines plotted, hypotheses confirmed and papers published, there is still room for explication, chomping over and celebrating the significance of ideas and the relevance they hold to us as finite individuals. The artistic instinct brings out and makes personal – makes gratifying and candid and spontaneous – these deeper layers of reality peeled back through scientific exploration.

Notes

[1] Though the oldest known proof of Pythagoras’ theorem was that given three centuries later by Euclid; please also note that the algebraic forms stated here were not used until Descartes applied algebra to geometry in the 17th century.
[2]…and “sisterhood”: women, who otherwise got a raw deal in the Ancient Greek world, were admitted as equals by the Pythagoreans.
[3] Interesting to note that Pythagoras’ father Mnesarchus was supposedly a jewel engraver: perhaps the regularity of crystal forms inspired this geometric ontology.
[4] See Godwin 1993 for a detailed history of the discourse surrounding the “Music of the Spheres”, covering astronomy, philosophy, mysticism.
[5] Himself incidentally the teacher of Lorenz Mizler, who founded the *Sozietät der Musicalischen Wissenschaften* to promote the development of a musical science based on mathematics, and whose most renowned member was none other than Johann Sebastian Bach.
[6] It is far-fetched to think that appreciation of harmony involves any sort of calculation in a literal sense, whether conscious or not.
[7] Leibniz developed this concept between 1676 and 1689. For more on the debate surrounding the *vis viva* see Smith 2006.

[8] The original wording of their German conversation was never recorded, Sibelius reporting the phrase "djupa logik" in Swedish to his biographer Karl Ekman. I'm grateful to the Sibelius scholar Andrew Barnett for clarifying this matter (Barnett 2007, 185).
[9] *"Le cœur a ses raisons, que la raison ne connaît point"* (Pascal 1669, IV.277
[10] i.e. what is now commonly known as the 'butterfly effect' in chaos theory: in nonlinear systems, a small change in initial conditions can cause very large differences at later states.
[11] Perhaps this Goldilocks-like balance between sterile order on the one hand, and chaotic complexity on the other, is necessary for the evolution of intelligence? The world cannot be too predictable, otherwise higher intelligence has no need to evolve beyond simple algorithm; too random and no mind can second-guess it. "Just right", on the infamous Edge of Chaos, and brains will flourish, coaxed by biological success to evolve ever greater and more subtle architectures. If a similar balance between cosmos and chaos – between Apollonian and Dionysian – regulates aesthetic fascination, then it is no surprise that we find the natural world beautiful. Beauty is a precondition for the existence of intelligent minds.
[12] Any number of clockwork mechanisms can be fabricated into a qualitatively similar set of clouds…'universality' here refers to the phenomenon of large scale systems displaying properties that are independent of the properties of the interacting parts.
[13] e.g. Newton's demonstration of the spectral dispersion and recombination of white light with prisms. The experiment unveils hidden truths about physical reality even though Newton's own corpuscular model of light, which he thought his experiments supported, was wrong.

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