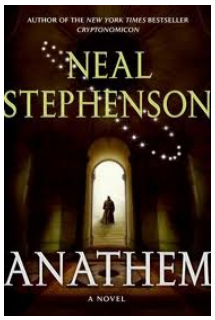
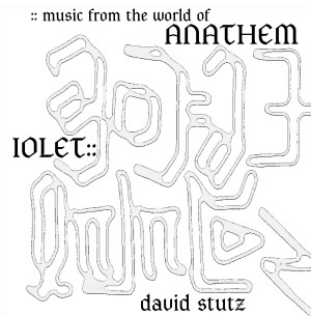
Anathem *Neal Stephenson*, Harper, 2009 (981 p.), pocket, ISBN 978-0061474101.
Iolet, Music from the world of Anathem, *David Stutz*, CD Baby, Audio CD, 2008, (54.27 min).
The Long Now Foundation, Quantum Physics, Philosophy, and more.



Neal Stephenson







David Stutz

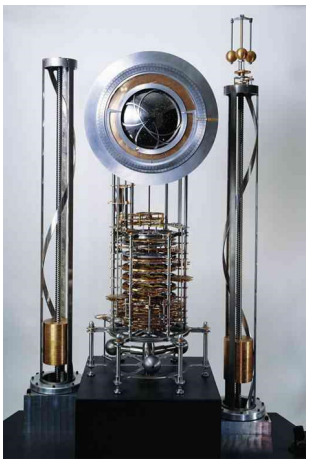
Neal Stephenson is best known from his novel *Cryptonomicon* (1999) which was all about cryptography, and his *Baroque Cycle* (8 books in 3 volumes: Quicksilver[1], The Confusion, The System of the World, 2003-2004), which dealt with the history of science in the 17th and 18th century is Europe. His science-f[a/i]ctional work got several prizes. His *Anathem* of 2008 is again an SF novel set in a distant future on a planet Arbre that is different from our world, yet very recognizable. The author got the initial idea for this novel when he was working on his *Baroque Cycle* and heard about the *Long Now Foundation*.



Logo of Long Now Foundation

This Foundation was initiated by *Danny Hillis*, an engineer and inventor, who started the idea already back in 1986 to construct a clock that should work for 10,000 years. The underlying incentive was to react against short-term thinking. He was backed up by *Stewart Brand*, a biologist and visionary pioneer who started the Foundation. A first prototype of the clock was finished in 01991 and is now on display in the London Science Museum. A second prototype was finished just before the end of 01999, so that it could chime when 02000 started. And all chime-melodies are unique since the musician *Brian Eno* also got involved and designed the melodies that will never be the same during the 10K years. The whole clock is a purely mechanical construction, no electronics at all. Finding out which melody to play next and the orrery (the sphere on top shows horizons) is calculated by 'the slowest mechanical computer on earth'. A special melody will be played every year, decade, century, millennium, and 10K years. This gave Stephenson the idea of humans visiting the clock when the gates opened, but when they were still inside when the gates closed they were confined to stay inside for 1, 10, 100, or 1000 years. In fact that is exactly what happens in *Anathem*.

Currently the construction of the first full size clock has started in a mountain in Nevada (more clocks are planned). *Jeff Bezos*, the CEO of `amazon.com` owns the place. The clock is huge, about 200 feet (61 meter), and visiting the clock to read it would take you a whole day, like being on a spiritual journey, climbing spiral stairs. Going up there is the only way to read off the time. To avoid energy consumption, the indicated time will be fixed until somebody wants to read it. Human input of energy is welcome while somebody is visiting, but using for instance the temperature differences the machine should harvest enough energy to keep the clock going on its own for thousands of years. Much more about the clock and the Long Now Foundation can be found on the web.



10,000 year clock (prototype)

Back to *Anathem* now. The story starts in the year 3982 A.R. on planet Arbre. The 'Reconstitution' in the year 0 was the consequence of the 'Terrible Events' that had happened because irresponsible scientists had brought apocalyptic catastrophes over Arbre after some 3500 years of 'Praxic Age'. The Reconstitution reorganized society such that there is a strict separation between the 'sæcular community' where all the 'praxic' (technology) is freely available such as 'jeejahs' (mobiles) 'speelycaptors' (camcorders), the 'Reticulum' (Internet) etc, and on the other

[1] See review in this Newsletter, issue 54, Sept. 2005



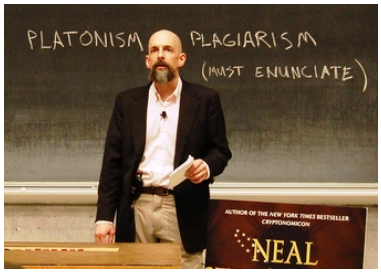
Chime generator of the long now clock

hand the 'mathic world' where 'avout' (scientists and philosophers), live in 'concents' (abbey-like communities) all over the planet according to strict rules written down in the 'Discipline' but deprived of all technology. The avout, both 'fraas' (male) and 'suurs' (female) are not allowed to breed, but every year there is a 10-day 'Apert' when the gates of the concents open and both societies can interact. On that occasion young people are recruited to join the mathic community. Depending on their talent, they will stay inside without interaction with the outside world for 1, 10, 100, or 1000 years and take a vow to become an 'unarian', a 'decenarian', 'centenarian', or possibly reach the highest status of 'millenarian'. The avout use the old language of science 'Orth' (like Latin used to be on earth in former centuries) while the sæcular world uses 'Fluccish' (but fortunately the novel is written in English).

As the previous paragraph illustrates, Neal Stephenson has put much effort in designing a new vocabulary. Often the words sound familiar if you know some Latin and Greek, but it will take the reader some 50 pages or more to become a bit familiar with it. Fortunately there is a 20 page dictionary at the end of the book and it needs a great deal of looking up words again and again in the early stage. Also in the text you will find at random places extracts from 'the dictionary, 4th edition, 3000 A.R.'. For the book a whole universe is created somewhat like *Frank Herbert* did for *Dune* or *J.R. Tolkien* did for *The Lord of the Rings*. When it appeared, it rapidly became a hype. Partly because it was related to the Long Now Foundation project and partly because Neal Stephenson had already a group of addicted fans. Add to this a good merchandising campaign and the result is that wiki and blog pages pop up where people discuss about interpretations of *Anathem* much like 'trekkies' never get enough of their *Star Trek*. At such sites you may read that *Jeremy Bornstein* has designed an elaborated version of Orth grammar, completely with declensions, conjugation, and pronunciation; and *Steve Wiggins* invented an orthographic alphabet etc (you may find more details on `www.monastic/orth`).



S. Brand, N. Stephenson, D. Hillis

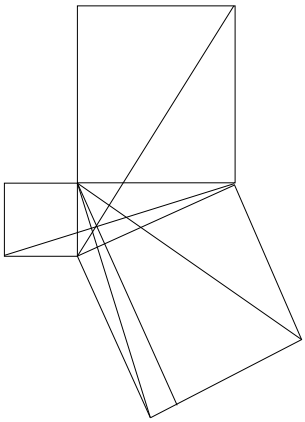


Stephenson lecturing about Anathem at MIT

Although this is a very thick novel, the adventurous part of the plot is relatively simple. Simplifying things considerably, it comes down to this. The main character who tells the whole story is Erasmas, a decenarian who attends the clock of his concent that has to be ringed with different melodies for the different 'auts' (rites). At some point his tutor Orolo, and later he himself, detects that Arbre is observed by an alien spaceship. When the situation becomes threatening, the 'Sæculum Power' summons avouts from all over the planet to organize a 'Convox' (an world-wide conference) where scientific and technological knowledge of Arbre is joined to attack the spaceship.

If you have read this far, you may wonder why this review should be in a Newsletter for mathematicians. Well, Stephenson got his 'scientific basis' for the novel from the work of *Roger Penrose*. In particular quantum physics and the many-worlds interpretation. In a nut-shell: every possible outcome of an event does exist in its own world. Thus there is an infinity of possible worlds or universes where all things that could have happened in your past (but didn't in your experience) did happen and are real in their own universe. It is essentially denying wavefunction collapse. In the novel, this idea is used because it turns out that the spaceship is inhabited by people from four different world tracks and live on separated concentric shells of the ship. Near the end of the book the narrative, faithful to the overall idea, also splits up in different possible realities. Penrose argues in his *The emperor's new mind* (1989) that the human brain operates like a quantum computer. Thus it is a contradiction that the different possible tracks of what has happened can be remembered and told by one person at the end. In principle, the different

world tracks can not interact. Stephenson solves this problem by a theory of directed acyclic graphs. Therefore he takes recourse to 'Platonic realism', a branch of philosophy where abstract 'universals' exist independently of particular realizations. It claims for example that mathematics is not created but it is discovered. So, according to Stephenson, in state space (called 'Hemn' space in the novel) there exist many distinct universes, all corresponding to a node in a graph connected by arrows indicating 'causality'. The state of a universe at a certain 'instance' or node is defined by its 'past', i.e., by the nodes that precede in the graph. So every universe has its own history, but some of them will be very close to ours because of overlapping nodes in the past. Just as many nodes have influenced our universe, we shall be influential for many future nodes, and this is how different universes can interact. Cycles are excluded because in a loop the future would also be the past contradicting causality.



The Bride's Chair

There is a lot of philosophical argumentation in the novel between the 'Halikaarnians', defending what we call mathematical formalism and 'Procians', adepts of what we call Platonic realism. In the concents, sometimes such discussions take on the form of a 'Dialog' which is a formal way of discussion or written report following certain rules. Since these argumentations take a relatively large number of pages, the reader should have enough interest in these matters or he/she will put the book aside before reaching the end. But there are also many less philosophical droplets of mathematics from time to time. The most striking one is the fact that the spaceship is not some fancy 'Star Wars' kind of construction, but it has the form of an icosahedron and it has a logo on one of its faces consisting of a number of lines forming a configuration known to us as the 'bride's chair'. That is the graphic used by Pythagoras to prove his well known theorem (called 'Adrakhonic theorem' in the novel). Therefore the aliens are called 'Geometers' for a certain period. One of the 'Dialogs' that a 'fid' (a young avout who just entered the concent) had to memorize was a verbal proof that the square root of 2 is irrational. Another example: if in a concent, an avout misbehaves, he or she is sequestered and has to learn a chapter from 'the Book'. Chapters are numbered from 1 to 12 and the number gives the severeness of the punishment. Chapter 1 is for young fids and requires about 2 hours to master it, while chapter 12 is almost like a life sentence. Three avouts finished chapter 12 after 3960 years but came out completely insane. Erasmas gets chapter 4, which contains 5 pages of digits of π. To be dismissed he 'had to know them as thoroughly as a student of quantum mechanics has to know group theory'.



D. Stutz and choir at the Anathem Launch Event

Some more examples: the 'Teglon' is related to Penrose's aperiodic tilings. A decagon contains seven different kinds of tiles, each with a groove on its top face. The problem is to lay the tiles in such a way that the grooves form an uninterrupted line over a large surface. The solution is hard since it is aperiodic. Fraa Jad, a millenarian, is able to find a solution in one night. Off line Stephenson admits that this is probably nonsense and that a mathematician could probably prove it to be wrong, but he just wanted to claim that aperiodic tilings is an important branch of mathematics. He also acknowledges *Kurt Gödel*. In the novel, one of the aliens by the name of Jules Verne Durand, mentions Gödel's name explicitly as if he had existed on Arbre. One of the novel's appendices presents a 'calca' (a lesson) where a cake-cutting problem is analyzed. It is related to the problem of doubling the square, an obvious reference to *Plato's 'Meno'*. The second appendix is a calca about the configuration space for 2D-motion, and the third is a discussion of the complex Platonic realism explained above.

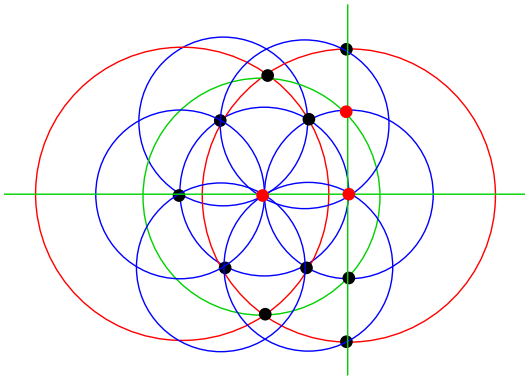
On his web page, Neal Stephenson writes that he does not claim any credentials as a scientist, mathematician or philosopher. Besides Penrose and Gödel he also cites many other scientists and philosophers as sources of inspiration.

The one thing I did not mention so far is the *music of Anathem*. The different melodies played at the 'auts' were some kind of communication, telling the whole community what was happening. So during the Anathem Launch Event at the Long Now Foundation in 2008, one of the acts was the performance of the Anathem music composed by David Stutz. To explain their strange outfits, one should know that the avout had only three things they could call their own: a bolt, a chord and a sphere. This made them look like monks. The sphere was an object that could be deformed, made of 'new matter' and was a multipurpose instrument.



David Stutz at the Anathem Launch Event

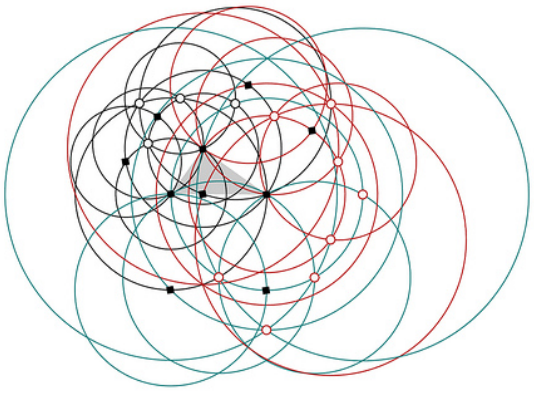
The music is available as a CD and its returns go to the Long Now Foundation. There are 8 pieces of music that sound like a mixture of Gregorian songs, Tibetan Buddhist monks meditating and the Tuvan music of Huun-Huur-Tu. These songs have titles like 'The Approximation of Pi', 'Thousander Chant', 'Proof (using finite projective geometry)', 'Sixteen Color Prime Generating Automaton', etc. The titles are suggestive of how they have been composed. For example the piece 'Cellular Automata' is composed as follows. A cellular automaton is a discrete system consisting of a regular grid of cells that have a finite number of states. The state a cell will be in at the next time instance depends on the states of its neighboring cells according to certain rules that are uniform over the grid and constant in time. Conway's *Game of Life* is one of the best known examples. Similarly, each singer may decide on a certain chord to sing and 'compute' his or her song on the fly as the choir evolves according to some prescribed automaton rule. On the CD, there is a 'master of automata' who regularly calls out a rule number (in Orth) to change the patterns.



Mascheroni circles to construct orthogonal lines

Once you know the rules of the game it makes sense and you will see the pattern. However reverse engineering, i.e., trying to find the rules that constructed the song, given only the song, is practically impossible unless you get a lot of hints. So here is another explanation that can be found on Stutz's website `synthesist.net/music/`. He has a fascination for the link between geometrical concepts and composing music. By mapping points, lines, intersections etc to certain musical counterparts, one may come a long way. However when he tried to compose a musical version of the proof of Pythagoras' theorem, something that could not be put aside in the framework of Anathem's music, the problem was to translate the geometric notion of 'length'. As long as it concerns integers, it could be represented by rhythm, but for rational numbers or transcendental numbers (and these are obviously needed in Pythagoras' theorem) he got into trouble. So he had to find another approach.

Traditionally Euclidean geometry uses only ruler and compass. *Georg Mohr* proved in 1692 that one can do without the ruler. However this fact went by unnoticed by *Lorenzo Mascheroni* who published the same result in his *Geometria del compasso* in 1797. That's why it became known as Mascheroni circles. The figure above shows how to construct (points on) orthogonal lines, and if the radius of the blue circles is the unit, one is halfway in constructing the (red) corners of a unit square. The explicit notion of length has been removed since one does not have to 'measure' any length. The relevant points result as intersection of circles. In the other plot to the right there are 22 circles and 22 points that are relevant in the construction of the shaded right triangle. Stutz made a map of these points (centers and/or intersections) and radii, and used this to turn it into a musical pattern that sounded pleasing to his ear. For obvious reasons this piece is called *Mascheroni circles* on the CD. It would be a hard 'calca' for the 'fids' in *Anathem* to find a proof of the 'Adrakhonic Theorem' in this labyrinth of circles.



Mohr-Mascheroni circles

Adhemar Bultheel