Newsletter

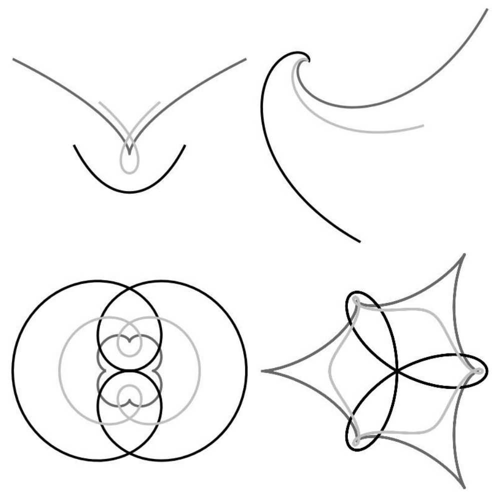
BELGIAN MATHEMATICAL SOCIETY

123, May 15, 2019

Comité National de Mathématique CNM

C W N M

NCW Nationaal Comité voor Wiskunde



Newsletter of the Belgian Mathematical Society and the National Committee for Mathematics

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Contents

The next edition of this newsletter will appear on September 15th, so from now till September 10th all content is welcomed very much at wendy.goemans@kuleuven.be.
Any information that you qualify as interesting to be spread among the Belgian Maths community is very much welcomed! Examples of such information are: PhD defenses, seminars, conferences, workshops, meetings, interaction with other sciences or business companies, popular lectures, school initiatives, math exhibitions, job opportunities, . . .

The President's Foreword

Dear members of the BMS,

Mathematics is fascinating, useful and universal, but most of our fellow citizens would argue that it is dreary, drab and reserved to an elite. In order to be able to share and disseminate our enthusiasm, we first need to break the barrier of indifference/hostility with which our craft is often met. One possible seed that we can plant in the People's minds is Mathematics' usefulness: our science is at the very core of most recent technological and scientific advances and our modern way of life would simply not be possible without mathematics! Such arguments might nevertheless not be as effective as we might hope, because People are generally not as receptive to facts as one might expect they would be. Perhaps it is more effective to laud Mathematics' beauty by exhibiting the amusement and awe that it can generate. Of course, the beauty and amusement of many mathematical statements is infinitely harder to fathom than that of a champion's league football match or a catchy pop song. There are nevertheless some amusing and beautiful statements that everyone can understand, even with only basic knowledge of arithmetic. One such statement that I have only discovered recently is that the decimal representation of the number

$$\frac{1}{99999999999999999999999\mathbf{8}999999999999999999999999}$$

generates the Fibonacci sequence in order, as can be checked easily on a smart phone through Wolfram Alpha for instance. Other remarkable statements abound, and could be used to lighten the mood and spark interest during classes or lectures to non mathematically inclined audiences. If you have more such mathematical trivia, please don't hesitate to share it either by mail to the BMS address, or via our FaceBook page.

We wish you all a good end of this academic year.

Yvik Swan,
BMS President

1 News from the BMS & NCM

1.1 Godeaux Lecture on June 3, 2019, KU Leuven Campus Kulak Kortrijk

The research group "Algebraic Topology and Group Theory" of the KU Leuven Campus Kulak Kortrijk is organizing a conference on **Nielsen Theory and Related Topics** from June 3–7, 2019. See https://www.kuleuven-kulak.be/nielsen for more information on the conference.

The program of the first day of the conference consists of series of talks aimed at non-specialists and also includes the 2019 Godeaux Lecture.

Program of the first day
All lectures take place in room B422.

- 09h20 – 09h30: Opening of the conference.
- 09h30 – 10h30: **Godeaux Lecture:** John Guashi (université de Caen Normandie, France):
  Fixed point theory of n-valued maps, configuration spaces and braid groups

- 10h30 – 11h00: Coffee Break
- 11h00 – 12h00: Tatiana Fomenko (Moscow State University, Russia): *Nielsen theory and related topics in recent papers by Russian authors*
- 12h00 – 13h30: Lunch
- 13h30 – 14h30: Iván Sadofschi Costa (Universidad de Buenos Aires, Argentina): *Nielsen theory and the fixed point property for simplicial complexes*
- 14h30 – 15h30: Kate Ponto (University of Kentucky, United States of America): *Nielsen theory through a stable homotopy theorist's eyes*
- 15h30 – 16h30: Coffee Break + Poster Session
- 16h30 – 17h30: Nirattaya Khamsemanan (Sirindhorn International Institute of Technology, Thailand): *Gait Recognition*

Abstracts of these talks will be available on the website of the conference soon.

Participation for this first day is free, but we would appreciate it if you would send an e-mail to prof. Karel Dekimpe (Karel.Dekimpe@kuleuven.be) if you intend to come. In case you want to have lunch at the student restaurant you have to order this in advance (the latest at May 20, also by sending an e-mail to prof. Karel Dekimpe) and the cost for non KU Leuven staff or students is 15 Euro. (Feel free to bring your own lunch.)

1.2 Bulletin of the Belgian Mathematical Society - Simon Stevin

In March 2019 Volume 26, Number 1 of the Bulletin of the Belgian Mathematical Society - Simon Stevin appeared with the following table of contents:

For the table of contents of previous issues, see https://projecteuclid.org/all/euclid.bbms.

Remember, as a member of the BMS you can ask for electronic access to all electronically available issues of the bulletin, if you don't have a login yet, contact pcara@vub.ac.be.

2 Meetings, Conferences, Lectures, ...

2.1 June 2019

Workshop on Nash Blow-up and Semple Tower, II

June 3-7, 2019

KU Leuven

See all information at https://nash-semple.sciencesconf.org/

Summer school "Finite Geometry and Friends"

June 17-21, 2019

Vrije Universiteit Brussel

This summer school will be centered around lectures given by

- Aida Abiad (University of Maastricht, The Netherlands)
- Nicola Durante (Universita degli Studi di Napoli, Federico II, Italy)
- Francesco Pavese (Politecnico di Bari, Italy)
- Geertrui Van de Voorde (University of Canterbury, New Zealand)

Each of these will deliver four hours of lectures on topics in their domain of expertise. Attending students and researchers will encounter a variety of topics, including algebraic graph theory and applications, blocking sets, linear sets, subspace and MRD codes and groups acting on geometries. Complementary to the lectures, the schedule will include exercises on the lecture material, open problem sessions, introductory GAP sessions and room for contributed talks (15-20 minutes).

For more information, we refer to the website: http://summerschool.fining.org.

We hope to see you in Brussels soon,

Jan De Beule
Sam Mattheus
Philippe Cara

Belgian-Dutch Algebraic Geometry Day

June 21, 2019

University of Amsterdam (The Netherlands)

See all information at https://www.math.ru.nl/ bmoonen/BNL.html

2.2 Save the date: Bourgain day

A Bourgain day will be held on Thursday 31 October 2019 in Brussels. Details follow in the September issue of this newsletter.

3 PhD theses

Fixed point properties for low rank linear groups over orders and applications to integral group rings

Doryan Temmerman
Vrije Universiteit Brussel
May 24, 2019 at 16:00
Auditorium E.0.12,
VUB Campus Etterbeek

Thesis advisors: Prof. Dr. Eric Jespers (Vrije Universiteit Brussel) and Dr. Geoffrey Janssens (Vrije Universiteit Brussel)

Summary

The most natural question to ask in representation theory of finite groups, is whether the representations determine the underlying group. More concretely:

"Does an isomorphism (as rings) between RG and RH imply an isomorphism (as groups) between G and H?"

This is the so-called *isomorphism problem (over R) for groups*, where R is a unitary ring. It appears that, in characteristic 0, $R = \mathbb{Z}$ is the universal case to consider. In other words, if the isomorphism problem holds for a ring R, then it also holds for $\mathbb{Z}$. It was however shown, around the turn of the century by M. Hertweck, that the answer is, in general, no. Nevertheless the problem to what extent $\mathbb{Z}G$ determines G remains central.

This problem — as many others in the theory of group rings — essentially comes down to understanding the group of units $\mathcal{U}(\mathbb{Z}G)$ of $\mathbb{Z}G$, and in particular the subset of units of finite order (called torsion units). This unit group is a finitely presented group, hence allows geometric group theoretical methods. This thesis is on the crossroad of ring theory, (geometric) group theory and representation theory.

The research can be split in two parts: (1) constructing large rigid subgroups of $\mathcal{U}(\mathbb{Z}G)$ in a generic way (i.e. independent of the concrete group G) and (2) investigation of actions of $\mathcal{U}(\mathbb{Z}G)$ on, a.o., trees and the existence of global fixed points thereon. The latter is done with an eye towards the existence of rigid decompositions of $\mathcal{U}(\mathbb{Z}G)$.

Concerning the first part, a few types of *generic constructions* of units of $\mathcal{U}(\mathbb{Z}G)$ have been found over the years, and many were of infinite order. In the nineties it was shown that some of these generic constructions generate *free groups*. In contrast free products of finite groups were not studied to exists in $\mathcal{U}(\mathbb{Z}G)$. In the first part of this thesis, we use a recently discovered generic construction of torsion units to show that, under mild conditions, *free products of finite cyclic groups* do indeed exists and can be explicitly provided when G is a nilpotent group. We also provide a framework for more general constructions.

In the second part of this thesis we take a different approach and study the geometric *property (FA)* for the whole group $\mathcal{U}(\mathbb{Z}G)$. This property states that any action on a tree has a global fixed point. We give both a ring and group theoretical characterisation of when $\mathcal{U}(\mathbb{Z}G)$ satisfy the stronger "hereditary" property *(HFA)*. The key observation hereby is that property (HFA) for $\mathcal{U}(\mathbb{Z}G)$ can be reduced to the same property for special linear groups over (possibly non-commutative) orders, and it is in this field of research that lie the main contributions of the thesis. Actually this part of the thesis handles groups of the latter type of rank 1, complementing G. Margulis work on higher rank algebraic groups. On the level of $\mathcal{U}(\mathbb{Z}G)$, we obtain a dichotomy "property (T) / non-trivially amalagmated up to commensurability".

4 History, maths and art, fiction, jokes, quotations ...

4.1 Women of mathematics throughout Europe - A gallery of portraits

The touring exhibition "Women of mathematics throughout Europe - A gallery of portraits", realized by Sylvie Paycha, Magdalena Georgescu, Sara Azzalli and Noel Matoff, is held at the Library of Science and Tecnology of UCLouvain, place L. Pasteur 2 in Louvain-la-Neuve, from April 23 till July 1st, 2019. It consists in portraits and interviews of thirteen female mathematicians from different countries throughout Europe.

Details can be found here: https://uclouvain.be/fr/bibliotheques/bst/evenements/women-of-mathematics-a-gallery-of-portraits.html.

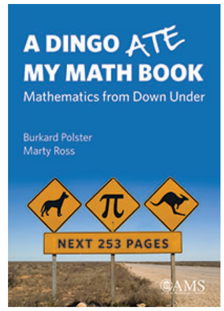
The full project is described here: http://womeninmath.net/.

See also the poster at the end of this newsletter.

4.2 Adhemar's corner

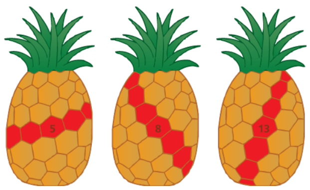
To read during a hopefully nice and enjoyable summer break, here follow two reviews of Adhemar Bultheel. The first review is on the book "A Dingo Ate my Math Book" of Burkhard Polster and Marty Ross, ideal for a warm summer eve. The second one is about Euler and his remarkable equation $e^{i\pi} + 1 = 0$ in the book "A Most Elegant Equation" of David Stipp.

A dingo ate my math book by *Burkhard Polster and Marty Ross*. AMS, Providence, Rhode Island, 2017, isbn 978-1-4704-3521-9 (pbk) xv+253 p.



B. Polster (L) & M. Ross (R)

The two authors of this book had a weekly mathematical column *Math Masters* in the Australian newspaper *The Age* from 2009 till 2014. The present book is a selection of 64 of the most "Aussie" flavoured of their contributions but the mathematics can be appreciated also by non-Australians. Moreover, since these columns are written for a general public, the mathematics are very elementary. Some of the themes are familiar and appeared also in other similar collections written by mathematical popularizing authors.



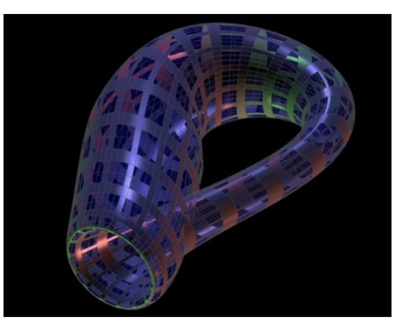
Big Pineapple

Each topic is just a few pages and usually ends with "a puzzle to ponder" (solutions can be found in an appendix at the end of the book). Enumerating all the topics here would be silly, but if you are familiar with popular mathematics books, you will recognize subjects such are organizing sports competitions, the trickiness of voting systems, Fibonacci numbers and the pineapple's hexagonally tiled surface, the traveling salesman problem, prime numbers, sphere packing, gambling, traffic problems (Braess's paradox: an extra road may be slowing traffic), etc.

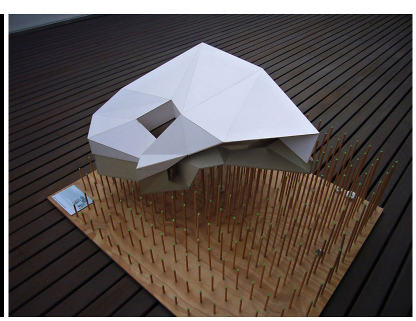
Interesting to read is their opinion about stereotype mathematical ideas (the golden ratio appearing everywhere in nature and that it is a key to beauty and perfection is a myth), and their critique on the Australian educational system that was implemented around 2009, almost banning mathematics completely (except from using a calculator).

Let me pick some of the topics that are related to remarkable Australian architecture (all the topics in the book are nicely illustrated). Left on this page you can admire the 16 m high *Big Pineapple* in Woombye, Queensland which is 'the biggest in the world'. Real pineapples have three families of spiraling sequences of hexagonal waffles with matching sides, and the number of these spirals is usually 5-8-13 or 8-13-21 (Fibonacci numbers, they grow with the pineapple), but the one in Woombye has 13 left and 13 right spirals and 26 vertical ones. Even if these are not Fibonacci numbers, they satisfy the theorem that says that on a cylindrical surface the largest number is always the sum of the two others.

Another remarkable building is the *Klein Bottle house* designed by Robert McBride and Debbie-Lyn Ryan, a beach holiday house on the Mornington Peninsula, 1.5 hrs drive from Melbourne. It is a playful design that resembles an origami version of a Klein bottle. The concept started as a spiral and while the tail of the spiral intrudes into the house, the idea of a Klein bottle-ish structure is realized.



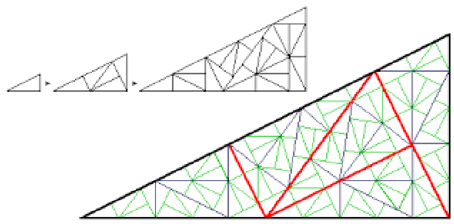
Concept



Scale model

Klein Bottle house

It cannot be a true Klein bottle because that surface is one sided. Thus there is no inside, and it would thus be impossible to live in.



pinwheel tiling

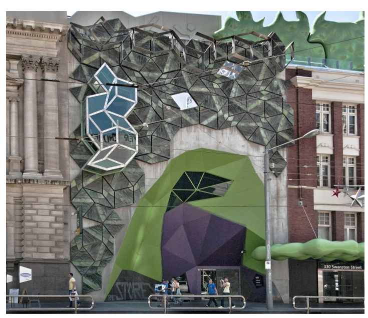
ACMI façade (middle)

ACMI close-up

The Federation Square in Melbourne has several remarkable façades decorated with triangular structures. In the book, the Math Masters picked the front of the Australian Center for the Moving Image (ACMI, that is the film museum), that has a pinwheel tiling. At least that is what it is supposed to be. Pinwheel tiling is illustrated above. Five rectangular triangles are pieced together into a larger triangle of the same shape, and this can be iterated to result in an irregular tiling of the plane. This idea is used to cover the ACMI façade. At least it works for the larger part of it up to 3 iterations, but then the left part breaks down at the third iteration step because the triangles of iteration 2 are not arranged in the same way as in the other level 3 triangles.

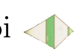
If we start from a triangle with orthogonal sides of length 1 and 2, then its surface is 1. Now we subdivide it into 5 smaller triangles of the same shape, and then subdivide the small triangle at the acute tip again and iterate this process, then we have a graphical proof that $\sum_{k=1}^{\infty} \frac{4}{5^k} = 1$. In fact, one could subdivide in $N > 5$ triangles and so prove that $\sum_{k=1}^{\infty} \frac{1}{N^k} = \frac{1}{N-1}$.

RMIT auditorium

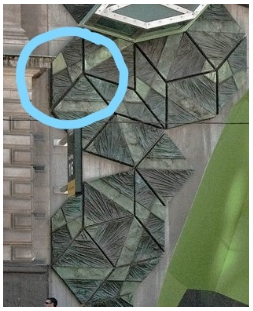


RMIT façade

RMIT close-up

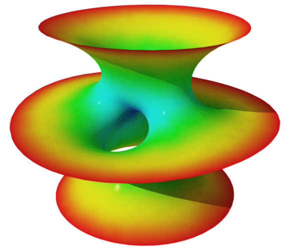
The Storey Hall of the Royal Melbourne Institute of Technology (RMIT) front façade has the intention to honor Penrose for his irregular tiling. Irregular tiling means that it is not possible to rearrange the tiles in a regular pattern. In 1973 Penrose found an irregular tiling with only 6 different tiles and later only 2 tiles were needed. This is simulated here with 2 (regular) rhombi that are also used in the auditorium (see picture). The big pentagon consists of five rhombi  decorated by a green strip and their green tip form the pentagonal center spot. The 5 vertices of the pentagon are completed using more acute rhombi that have two green spots at the apposing obtuse vertices. Unfortunately only one green colour is used for the decoration. These tiles can be easily rearranged to form a regular tiling. One needs only the rhombi with the green strip to fill the plane in a regular fashion. Hence it is not a Penrose tiling. If the two green decorations on every tile would be in two different colour, then they could form a Penrose tiling, but using only one decorating colour destroys the original intention. The same idea is used to tile the façade.

Note also that there are two blank spots in the front tiling. The reason is that the rhombi that fit into these holes do not have the proper decoration to blend with the surrounding tiles. This could be intentional, but on the left some tile is inserted that does not match the line pattern of the neighbouring tiles as can be seen on the encircled detail picture on the left below.

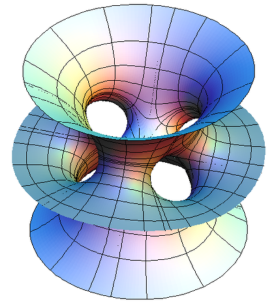


RMIT detail

Healesville Sanctuary



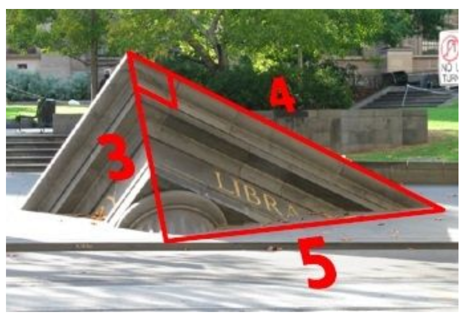
Costa surface



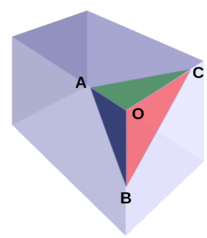
Meek-Hoffman-Costa

The Healesville Santuary is a zoo specializing in native Australian animals located in rural Victoria. The Health Center building has a remarkable mathematically constructed roof. It is a section of a minimal surface that is related to the (unbounded) Costa surface that was found by the Brazilian mathematician José da Costa in 1982. Before one only knew trivial minimal surfaces such as the plane, the helicoid and the catenoid. Later more general Meeks-Hoffmann-Costas surfaces were discovered that have n holes showing an n-fold symmetry when looked at from the top. A Costa surface has only two holes. The roof of the Health Center has three holes.

Architectural Fragment



in Swanston Street



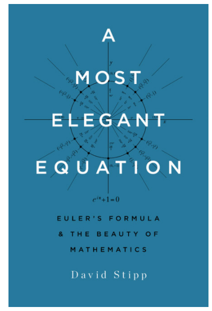
Gua's theorem

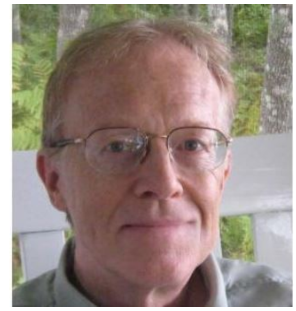
On Swanston street in Melbourne, outside the State Library of Victoria you can see the *Architectural Fragment* (1992) by Petrus Spronk, a Dutch sculptor who emigrated to Australia in 1957. As indicated on the picture above, the pyramidal form is a cut corner of a cube and the larger rectangular triangle has sides 3-4-5 meters, which is a Pythagorean triple because $a = 3, b = 4, c = 5$ satisfies the Pythagorean theorem $a^2 + b^2 = c^2$.

The Pythagorean theorem is about the sides of a rectangular triangle, which can be seen as a corner snipped off a square by a line cutting the two incident edges. The abstract pyramid that is like the Archtectural Fragment is a part cut off a cube with a plane that intersects the three edges that coincide at the vertex. Like on the picture on the right, we obtain a pyramid with three right angles at the top vertex O and an arbitrary triangular base ABC. The generalization of Pythagoras is not about the length of the edges, but about the surfaces or the four faces and it is known as Gua's theorem which states that $\mathrm{vol}_2(ABO)^2 + \mathrm{vol}_2(BCO)^2 + \mathrm{vol}_2(ACO)^2 = \mathrm{vol}_2(ABC)^2$ and this can be generalized to n-dimensional volumes. The theorem is named after Jean Paul de Gua de Malves who published it in 1783 but it was known much earlier by for example René Descartes (1596-1650).

Adhemar Bultheel

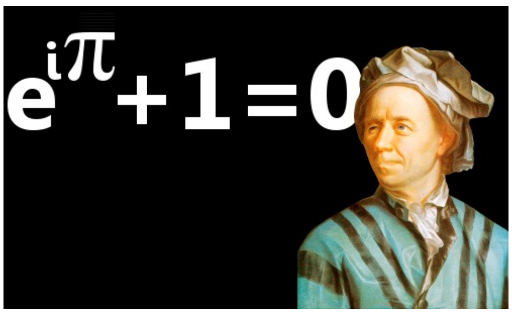
A Most Elegant Equation by *David Stipp*. Basic Books, 2017, isbn 978-0-4650-9377-9, 240 p.




David Stipp

David Stipp is a freelance science writer and with this book he delivers an eulogy of the Euler identity $e^{i\pi} + 1 = 0$ which is considered to be the most beautiful formula of mathematics. This was already done by Paul Nahin in *Dr. Euler's Fabulous Formula* (2006) but here the story is told at the level of beginning secondary school children.

There is of course an interesting story to tell. The equation has five fundamental mathematical constants: $\pi, i, 0, 1, \mathrm{e}$, and books have been written about each of them. Moreover Leonhard Euler was a very colourful personality to tell stories about, an open door for a science writers such as Stipp who very generously declares his admiration for the man and his formula.



First thing to do is explain what e is. He does this using the Bernouilli approach with the formula for compound interest $\mathrm{e} = \lim_{n\to\infty}(1 + 1/n)^n$. Next the notion of a function is introduced. In particular e^x, the only function that is equal to its own derivative. Therefore he introduces a derivative as an instantaneous change leading to a discussion with a police officer who used a speed gun and is giving a speeding ticked. Since e is irrational, this leads to an excursion about the notion of infinity.

The second fascinating constant to consider is π, a number that people associate with the circle, but that pops up in many other computations that are seemingly totally unrelated to circles (e.g. $\sum_{k=0}^{\infty} (-1)^k/(2k + 1) = \pi/4$, called Leibnitz series and the Basel problem: $\sum_{k=1}^{\infty} 1/k^2 = \pi^2/6$, as proved by Euler, etc.). To show this, Stipp also needs to discuss convergence of infinite sums.

The imaginary unit i is really provocative. Where a negative number could still correspond to for example a debt if the positive values represent an asset, there is not some real quantity imaginable that corresponds to the square root of a negative number. On the other hand it turned out to be very useful in computations. It popped up like a local glitch while solving a cubic equation and dissolved like an hallucination in the next steps to give eventually a real (and correct) result.

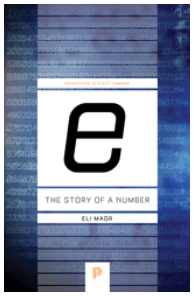
Time to give more details about the master himself. Stipp sketches a lovely picture of Euler as described by Dieudonné Thiébault who met him in mid-life and describes him as writing his immortal works with a child on his knees and a cat on his back. A social as well as a family man who loved joking, but who met a lot of misery in his life. Only two of his 13 children survived him, he lost eye sight in one eye early in life and he was almost completely blind when he lost his wife. He still did all the computations in his head and continued to be even more productive since. The Prussian king Frederick hired him to help develop the Berlin Academy of Sciences, but in a letter to Voltaire he called Euler the "great cyclops". When Euler left for Russia to work for Catherine II at the St. Petersburg Academy, the king wrote that the "one-eyed monster was replaced by another who had two eyes" (which was Joseph-Louis Lagrange).

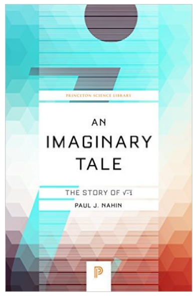
Euler fits in a list of the greatest of all times. Stipp compares the characters of two other great names of the Enlightenment that were in many ways the opposite of Euler's: Newton (who was a "shy, prickly loner who held grudges", "a tyrannical president of the Royal Society", and who had a fight with anyone criticizing his work like Hooke and Leibnitz) and Gauss (who disliked teaching, had few friends, alienated his son Daniel, was reluctant to publish his work, and humiliated János Bolyai who had discovered non-Euclidean geometry "praising his work would be like prising myself").

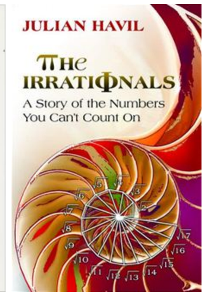
With the remaining constants 0 and 1, Stipp is a bit more poetical. The constants may be less glamorous than e, π or i, but they are not less important. For 1, Stipp quotes Alex Bellos who describes it as "independent, strong, honest, brave, straightforward, pioneering and lonely". Zero is "secretly peculiar", "as diaphanous as a fairy's wing, yet it is as powerful as a black hole".

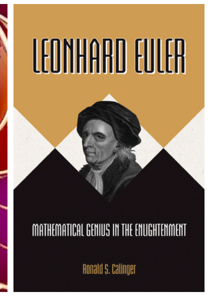
So, what could be expected from $e^{i\pi}$, a transcendental number raised to another imaginary transcendental number? The flabbergasting fact about Euler's formula is that this evaluates to the relatively simple

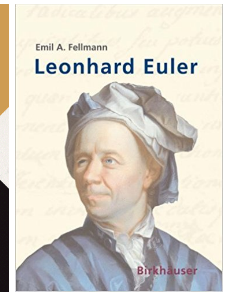
-1. To convince a mathematical novice in his early teens of this fact, Stipp again needs to introduce some extra mathematics. To start with, since he already defined a function, he needs to connect the sine and cosine, (defined as the ratios of the length of sides in a rectangular triangle) to a function mapping an angle $\theta \in [0, 90^\circ)$ to two real numbers $\sin\theta$ and $\cos\theta$ in $[-1, 1]$. To achieve this he introduces the goniometric circle and the Cartesian plane, which he does very patiently and very elementary. The formulas of De Moivre $(\cos\theta + i\sin\theta)^n = (\cos n\theta + i\sin n\theta)$ and the Taylor series of the trigonometric functions are the final elements that allow to prove Euler's formula. The geometric representation of complex numbers as vectors or points in the plane can visualize complex arithmetic and interpret a multiplication with $e^{i\theta}$ as a rotation, and hence associate complex analysis with oscillating phenomena. The latter made electrical engineers early adaptors of complex numbers to analyse their AC circuits.



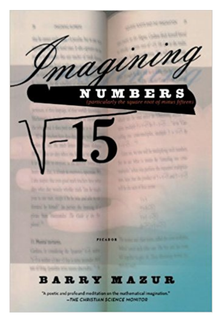


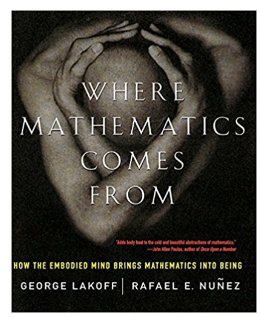






But most of all, Euler's formula is considered to be a (if not the most) beautiful formula in mathematics. This triggers Stipp to investigate what other authors have said in this regard and to ponder on what exactly is meant by (mathematical) beauty and on the Platonic versus the nominalist views on mathematics. He considers himself to be a "quasi-platonist". He believes that mathematics exists outside the human brain and has to be discovered, but he is not fanatical about it. I think this is a sensible thing to do. There is beauty out there that we can *discover*, and at other days we elaborate on the accumulated mathematical background and actually *create* theorems that are not obtained by observation. This is in line with Barry Mazur who describes this ambivalence in his book *Imagining Numbers*. He gives arguments to support his praise of the formula and he defends his views against other opinions that attack Platonism like George Lakoff, Rafael E. Núñez in *Where Mathematics Comes From*.





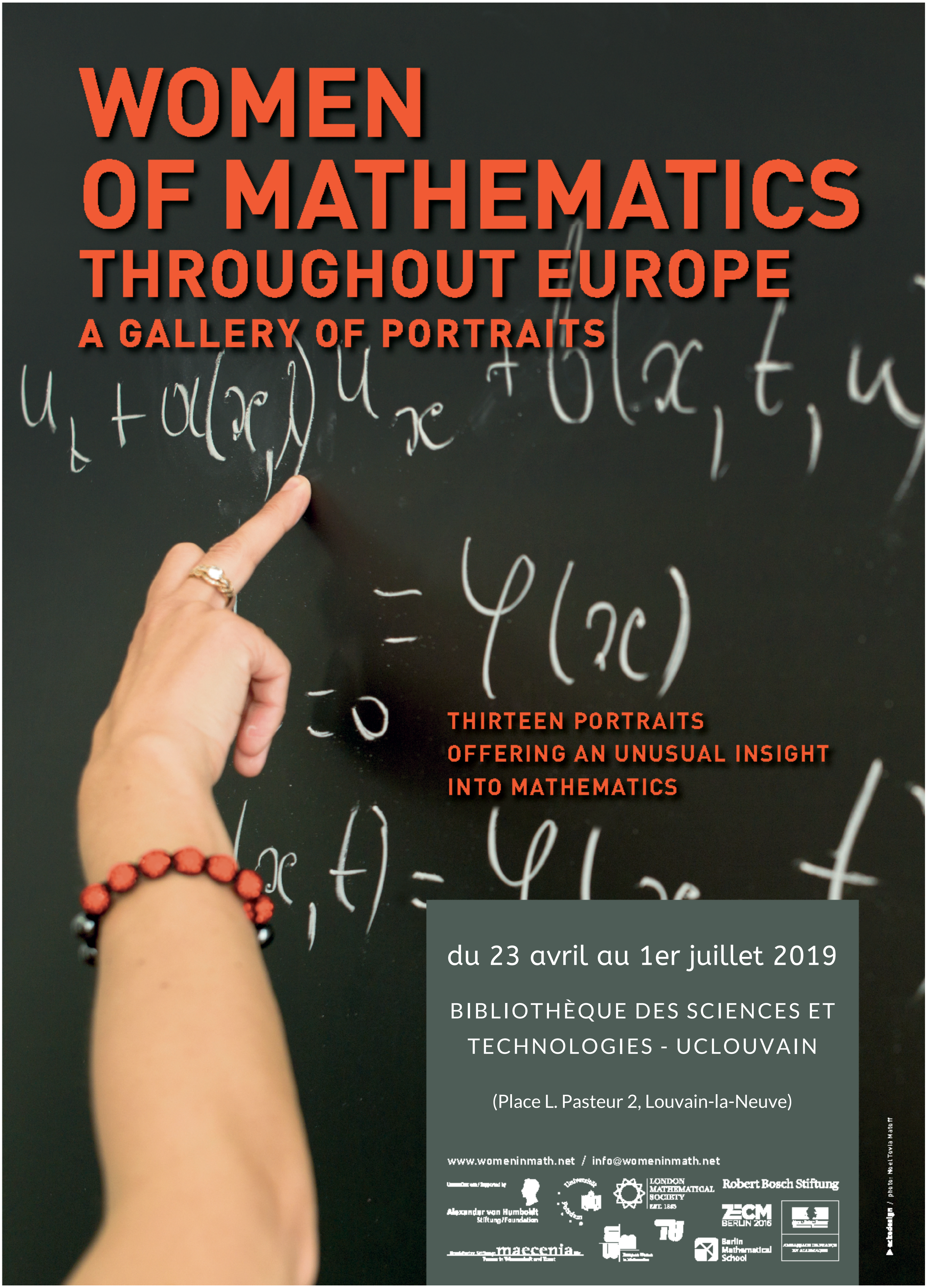
In an appendix, Stipp describes the original proof that Euler gave of his formula. It has been criticised for its dubious way he dealt with infinitesimals, but on the other hand he was excellent in explaining his way of thinking that led to the result. Nowadays only a polished paper is published, thereby loosing insight into the author's meandering path that eventually gave the result.

The last part (Platonism and appendix) may be less of interest to a 12-year-old, but the style of the whole book is fresh, witty and sparking with a lot of humour and hooking up with the modern media-world and language that the targeted readership is familiar with. To give just one example (there are a 'gazillion' of other examples) the square root of a negative number was considered in Cardano's time to be "perverse gobbledygook".

Some books on related material:

P.J. Nahin, *Dr. Euler's Fabulous Formula: Cures Many Mathematical Ills.* Princeton U. Press, 2017.
E. Maor, *e: The Story of a Number.* Princeton U. Press, 2015.
P.J. Nahin, *An Imaginary Tale: The Story of* $\sqrt{-1}$. Princeton U. Press, 2016.
R. Kaplan, *The Nothing that Is: A Natural History of Zero.* Oxford U. Press, 2000.
J. Havil, *The Irrationals. A Story of the Numbers You Can't Count On.* Princeton U. Press, 2012.
R.S. Calinger, *Leonhard Euler: Mathematical Genius in the Enlightenment*, Princeton U. Press, 2015.
E.A. Fellman, *Leonhard Euler*, Birkhäuser Verlag, 2007.
B. Mazur, *Imagining Numbers (Particularly the Square Root of Minus Fifteen)*, Picador, 2004.
G. Lakoff, R.E. Núñez, *Where Mathematics Comes From.* Basic Books, 2001.

Adhemar Bultheel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