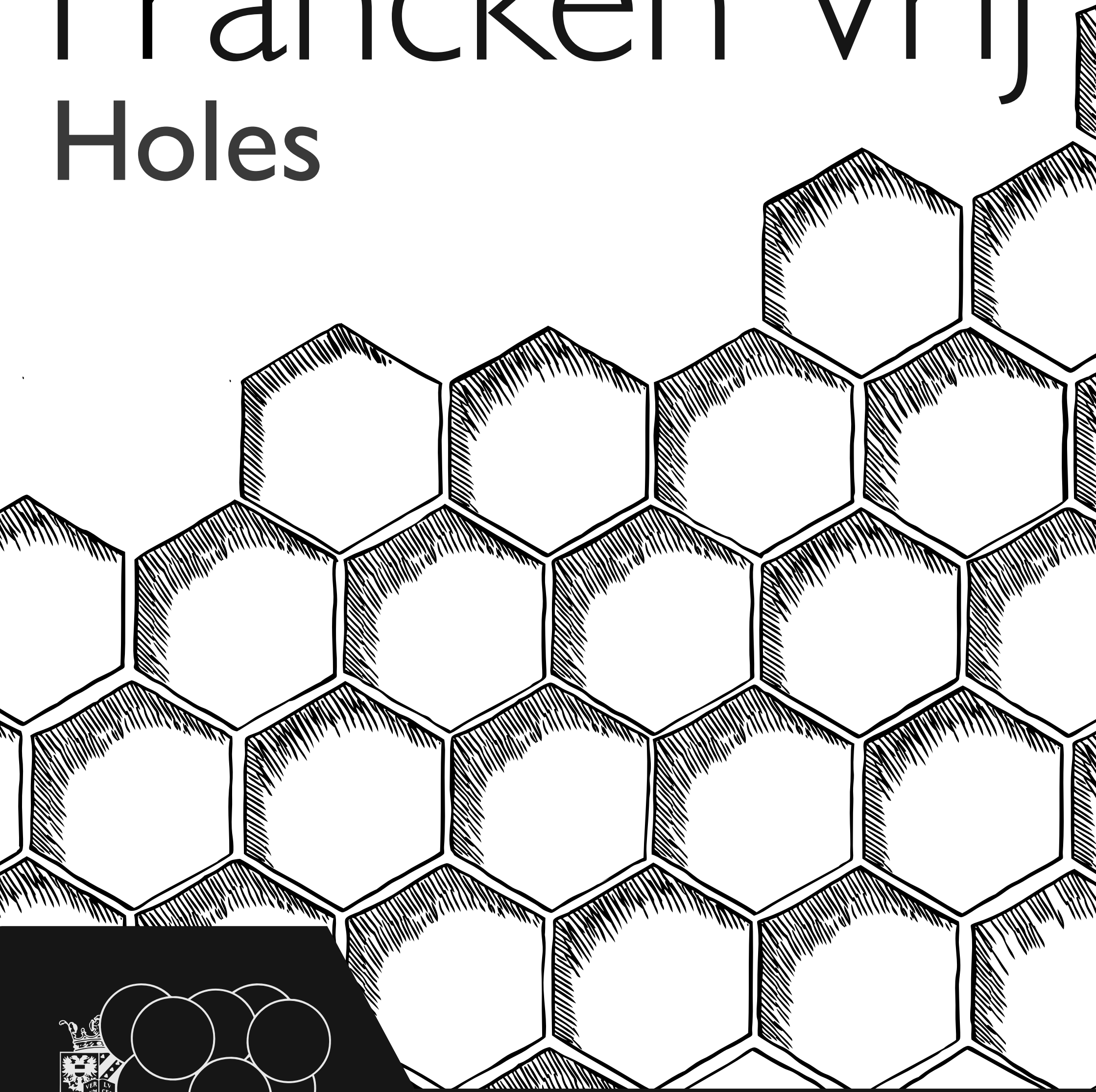
Prof. De Hosson
40 years of professorship in Groningen

Bor(r)el Distribution
A solid analysis of liquid statistics

Francken Abroad
Wi nøt trei an internship in Sweden this yër

Francken Vrij

Holes



22.1 Holes

Colophon

Editorial

This year the break of the Francken Vrij editorial board became a bit longer than expected, but finally you can read this first Francken of the academic year. Of course there is one thing from last edition to be finished: the puzzle. The answer of the puzzle was 'circle'. The winner of the puzzle is Emma van der Weele, she can request her mallard from Steven. This edition we don't have a puzzle, but we have a lot of other articles. I hope you will enjoy reading this edition!

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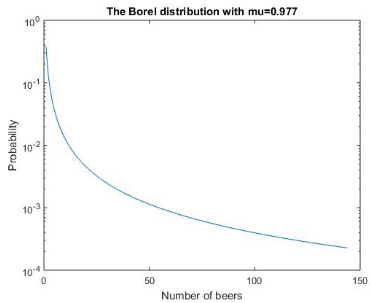
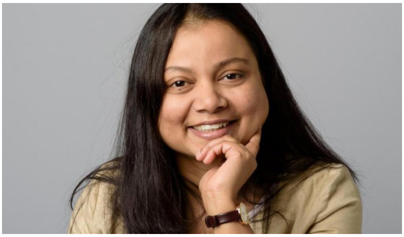
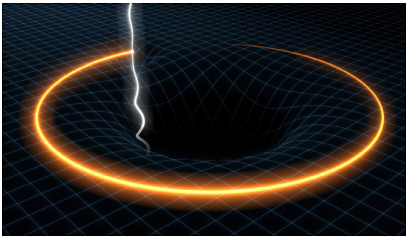


The Borel distribution with mu=0.977
Probability
Number of beers
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
50
100
150

Edition 21.1





Chair's Preface

By Kathinka Frieswijk

November. The days are getting shorter, the night's drawing in. Luckily, Francken offers plenty of opportunity to rage against the dying of the light, by organising lots and lots of amazing events during the cold autumn and winter days. My personal favorite was the jam session, where anyone could bear witness to the fact that Francken members are extremely capable musicians. '*Vo*!

It has been nearly six months since I jumped down the rabbit hole and became the president of our association. Time flies, except in the neighbourhood of massive objects, for example near (yo mama or) a black hole. Whilst I was writing this piece I did consider equating the Francken Vrij deadline with the Schwarzschild radius, where Francken Vrij readers would play the role of distant observers. Regarding the Francken Vrij deadline as the Schwarzschild radius, has several advantages. Firstly, even though I didn't make the deadline and went way beyond it, the readers of this piece would never observe me passing the deadline. Very convenient. Secondly, if this piece of text passes the Schwarzschild Radius, sentences would seem to die off very quickly.... which would enable me to stop writing.
Holes have always been an object of interest (even though a hole is defined as a lack of an object). While staring into the dark abyss, people have always wondered about the unseen world that is still to be discovered, the unraveled mysteries that lie ahead, and the possible dangers that might be involved. Exciting is the word, so I hope you will explore many holes in this brand-new edition of the Francken Vrij. *Lees'ah*!

News of the Association

By Anna Kenbeek

This is the first time I have the honour of giving you an update about what has happened in the association. The activity calendar was filled densely. Even though I will have to leave a lot of holes in this recap, it hopefully gives a nice overview of the epic activities during the last couple of months.

First week

During the summer break, the Francken room was not as crowded as usual, but still crowded, as it was used to watch the Tour de France and Game of Thrones. As the new academic year started again a whole lot of new people came in to make grilled cheese sandwiches, have a drink after their lectures and join activities. For some of us it was good to see everybody again and hear holiday stories and for everybody it was nice to get to know a lot of new students.

Applied Physics Quiz

In this exhilarating battle of wits, Francken members got the chance to show off their knowledge of Applied Physics, T.F.V. 'Professor Francken', music and various other topics. The winners, team '#FMF', were handed a beautiful inscribed trophee, where the team list happened to include the name of the person who made the quiz questions. Coincidence? I think not.

Applied Physics burger night

To give the new Applied Physics freshmen an impression of the association and its ambiance, Francken organised a dinner at Pappa Joe. While enjoying one of their delicious burgers and some drinks, they had a chance to get to know each other and older Francken members. It was an enjoyable night at our main restaurant.

September Barbecue

What is a September at Francken without a September barbecue? I wouldn't know, because also this year the September barbecue was organised and was a great succes. A lot of people came to enjoy more than enough meat, salads and beers and this event taught us that it is perfectly possible to barbecue in the rain. There was not a drip stopping us from filling every belly with delicious burgers, sausages and French bread or from having a great night.

Excursion Tata Steel

Anyone who was curious about the origin of their *stalen ros* had the chance to join the excursion to the Tata Steel location in IJmuiden. We got to see their terrain, covering a surface area of the same size as the centre of Amsterdam. Furthermore, there were two former Francken members telling about their work at Tata Steel and we got physical background information that was the basis to the steel production. Even though we did not always manage to keep our steely-eyed gaze, it was a very interesting and enjoyable day.

Casino Night

The casino in Groningen burned down, but those who wanted to play casino games without burning all their money, could still participate in the Francken casino night. Games such as blackjack, camel race and poker were played and members could finally put their scientific intuition into practice.

Practice Sessions

Our most important form of direct study support was proven to be a success again. Several practice sessions were organised for first and second year physics courses, where practice exams were provided and senior students were present to help. A lot of students used this to improve the results for their final exams.

Feesten met Francken - Mystery Hunt

The location of this year's mix activity with FMF was unknown. Fortunately about 50 members of both associations teamed up to find out where it was. During this mystery hunt the solutions to several puzzles led them to eight different locations in the centre of Groningen before they all finished at Café the Crown.

By Marten Koopmans

Fråncken Abrøad

Scandinavia has always been a tempting place for me to live for some time. Whether Sweden lived up to my Scandinavian dream I'll reserve for somewhere further into my 'stukje'. I'm Marten Koopmans and many of you will know at least my face, since I've been around since 2010. At our association I've been involved in the founding of one of the few committees purely consisting of applied physicists, the Brouwcie, and some of the chaos that followed. This is, with the current quest for equality we needed a very defendable committee composition, so therefore we have tried to diversify our committee with all kinds of different breeds of students, mathematicians and biologists possibly amongst others.

I'm currently finishing my Applied Physics master, specifically the 'Industrial internship' part. Since I've long had this Scandinavian dream, it made a lot of sense for me to do this internship in Scandinavia. While looking for an internship in Scandinavia a few countries came to my mind, two actually: Norway and Sweden. For me, Norway was the first country of choice. It has some beautiful terrain for those interested in a hike, run, or bike ride every now and then. It is also amongst the most advanced countries in Europe on the science and business side of things. When looking for an internship in Norway, however, one should take into account that it is not known for its liberal labour policies. In Norway a company is required to pay an employee according to their education. The wage for a bachelor of science would therefore be quite substantial, meaning that a company doesn't like to employ interns. They would earn too much money and add too little in their short stay. A project at a Norwegian university is a possibility however, but none of the universities had projects that fit me.

So Sweden it was! I exclusively looked for university related projects in Sweden and found a nice project in the medium sized town called Linköping. Linköping is probably most known for its Saab factories and university in Sweden. Saab, as some of you might remember, was the brand of car that your dentist used to drive until the car division went bankrupt in 2011. The airplane component of Saab however, is alive and kicking. They mainly produce the Saab Gripen jetfighter at the moment. A lot of work at the university is therefore focussed in the area of control engineering and other jetfighter related topics. The university works on many different topics obviously and amongst them is the currently very popular topic of perovskites. This is the topic that I'm working on and on which I will do a PhD at our beautiful university

An electron can fall back, or de-excite.

in Groningen in the near future. This might therefore not be the last 'stukje' you'll ever read written by me.
Perovskites probably sound familiar to at least some of you and I highly recommend some quality literature available for free on *en.wikipedia.org/wiki/Perovskite_(structure)* to whom this doesn't ring a bell. My project in particular was intended as a hands on experience before doing only computer simulations of these same devices during my PhD. I worked at the research group of dr. Feng Gao, a very nice and open research group that is focused on perovskites (LEDs and solar cells) and organic photovoltaics (again LEDs and solar cells mostly).
So what did I actually do? Well, I created LEDs in the lab, amongst other things. Creating such a LED (or solar cell for that matter) is quite satisfying work, as within one day, the entire cycle of making and measuring your devices is finished (and of course they emit light, which is just generally nice to watch).
The actual devices are produced as discussed next. First, one cleans the substrates on which these devices are to be produced. These substrates are glass with a coating of some conducting transparent electrode (quite a strict requirement). On that substrate one deposits a blocking layer by a process called spin coating. I am sure that people in the Francken room have heard a thing or two about this and rightly so, as it is a really cool process. The basic idea being: deposit some amount of desired liquid on your sample and then spin it very quickly. The centrifugal force on the droplet combined with its surface tension will make this droplet form a layer of equal thickness. I will leave the mathematical details of this claim to the reader as an exercise to regain some of the knowledge obtained during classical mechanics classes. So utilising this process we can create layers of uniform thickness on a substrate. Using this process we make two of our layers. Using another process, namely vacuum deposition we create two more. Vacuum deposition is a process which allows you to deposit thin layers of a desired material on the substrate, where the deposited material can be metallic or organic. The total device now looks like it does in Figure 1. Some basics of the device operation can be understood from this picture. The electrodes in the figure inject electrons and holes as indicated in the figure. Holes in this picture are in effect, mobile sites to which an electron can fall back,

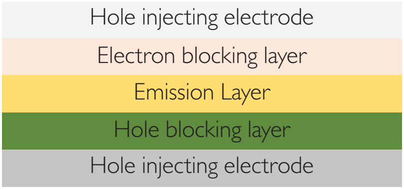


Figure 1: device structure.

or de-excite. They are treated as the opposite of electrons and have opposite charge (and thus will move in the opposite direction when under the influence of an electric field). Holes behave like electrons and can thus be conducted through a material just like electrons. Now when the electrodes inject holes and electrons respectively, they move to the middle of the device, the emission layer. They cannot move further, as they are stopped by the respective hole and electron blocking layer. Now that the electrons and holes are together stuck in the emission layer, they have a good probability of encountering each other. This encounter will result in a de-excitation of the electron in this free less energetic hole energy state and create a photon. As you might remember from a while back, one of our electrodes and the corresponding blocking layer are transparent. The light can then, hopefully, find its way out of the device and into our efficiency measurement device.

Now that the devices I made are hopefully a bit more clear to you, let's discuss the pressing issue of the weather in Sweden. The weather in Linköping is a bit different from the Netherlands. As is well known, the Scandinavian winters are quite tough. In Linköping the temperature can go to -20 degrees Celsius during daytime. Coming from Groningen however, even temperatures as they are right now, around zero degrees, are perfectly comfortable (courtesy of the more continental climate). For those very afraid of the temperatures at this longitude, this might be of some comfort. Even the sun can be seen quite regularly in this town, so I would argue that the weather is not worse than in Groningen.

One cool thing about being so far north is that the sun will always be relatively low. If you like to photograph things, or just watch things in general, you'll find that Sweden is very easy on the eyes. With my friends I always end up arguing that the same tree, city, or forest just looks more beautiful this far north. Although I would add that the winters here don't offer the true polar night experience you might enjoy in a place like Tromsø (Norway).

As I am now well past my 1000 word limit and the second deadline is still a few days away, I should probably stop writing before my 'stukje' gets out of hand. I would like to finish by inviting any of you that feel like going to Sweden, or Scandinavia in general, to ask me for help or advice if you think that might help you in any way.

Adjö!

Bor(r)el Distribution

By Steven Groen

When you come to ponder the occurence of holes in physics and cosmology, you might be inclined to think of black holes: objects that suck up all matter it can reach, and never spit any matter out. In the Francken room however, we regularly encounter a similar phenomenon: Francken members tend to consume endless quantities of beer, whereas it rarely ever happens that some of this beer is spit out afterwards. As Francken members have a scientific thought about just about anything, it cannot come as a surprise to the reader that we started analyzing, predicting and manipulating the precise behavior of this phenomenon. Although the upshot of the research described in this article originated from puns we could make with the names of mathematicians Émile Borel and Armand Borel, it turned out very fruitful and applied. Mark Redeman was able to extract the desired information from the database, and made a lot of progress in the interpretation and understanding of all this information. Credits.

Gert Eising is old

It may feel like a short while ago, but it is actually around 10 years ago that our member of merit Gert Eising devised the digital system that most of us know as the *streepsysteem*. This digital database registers every transaction in the Francken room: the person, the product, the time, the date and the total price. This has accounted for a rapidly expanding (beer) consumption database that forms the main subject of our study. At the time of writing, the total number of beers registered by this database is 116064. [1] With a data set this

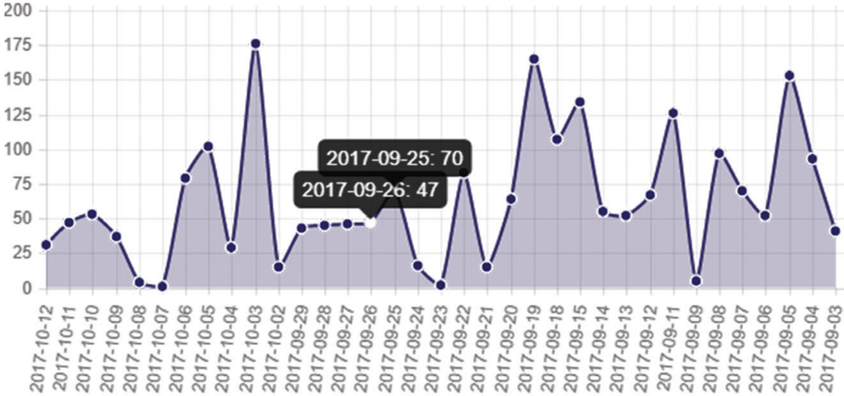


Figure 1: The number of beers consumed as a function of the date, plotted for a month.

large, we may say we are dealing with *big data*, a fashionable term that usually suggests not only that the data analysis you are performing is difficult, but also that it is important. Now that we have this term aboard, we may engage in our research. We focus our research on one aspect of the database: the number of beers that is consumed on a given day. In principal, the interest is both global (the total of the association) and local (pertaining to only one member). We first try day-dependent analysis, but (spoiler alert) this did not turn out a great success. However, our main result is that the Borel distribution provides an excellent day-independent approximation of our beer consumption.

Day-dependent analysis: Latrappe and Fierour

As mentioned, we study the number of beers consumed on a date as a function of that date. We wish to find a pattern in graphs like Figure 1, such that we find a fitting function. Ideally, this function provides an accurate prediction of the number of beers that will be drunk on some day. This is very useful for the Borrelcie, such that we always have enough beer in stock. There are two ways in which I (could have) tried doing this: Latrappe interpolation and Fierour analysis.

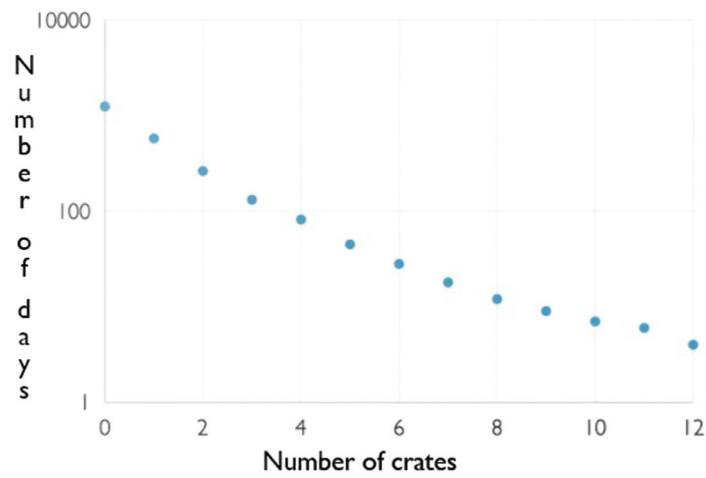
In Latrappe interpolation, we can use a selection of data points to approximate the drinking behaviour with a polynomial. However, this turned out not to be very fruitful: our data set does not behave as a polynomial (of small degree). The more data points we take into account, the more erratic our interpolant behaves. This makes sense: a polynomial tends to infinity or minus infinity if time tends to infinity. We want neither to happen to our drinking behavior. Fierour analysis suits our problem better. There is a clear period of a week; we drink less in the weekends. Similarly, the consumption shrinks (slightly) in the summer. However, there is not much more information to be found. Sometimes a Monday is *reëel*, but in other weeks there might be a beer-intensive event on Tuesday. This problem can be summarized as follows: there are too many unpredictable non-periodic external factors. Fourier analysis has been applied to other facets of the *streepsysteem*; we found that there is a stronger monthly period in the male chocolate consumption than there is in the female chocolate consumption.

The Borel distribution offered a solution to one of the most prominent open drinking problems

We find that there is no real result in our research so far. Moreover, there is no literal resemblance between our data and our fit. Time to turn to day-independent analysis.

Day-independent analysis: Borel

Since we are not content with our day-dependent fits, we must try day-independent analysis. This function tells us the probability of a certain number of beers being drunk on a given day: a discrete probability distribution. A question one might ask is: which discrete probability distribution? The answer came from an unexpected place. Some day, a group of Francken members decided to study mathematicians whose surname was Borel. One of them, Émile Borel, is known for formulating a discrete probability distribution, the Borel distribution. Although we were primarily interested in Borel puns (these puns had all been dibsed by Armand Borel, whose biography is an impressive collection of puns), the Borel distribution offered us much more: a solution to the day-indepent analysis problem, which was one of the prominent open drinking problems at that moment. This breakthrough was discovered when the Borel distribution was plotted using MATLAB: a striking resemblance with the borrel distribution (barbecues discarded), for which the *lustrumboek* provided a visual representation, occured to us. You can check this yourself in Figure 2. The Borel distribution was definitely the object to study.



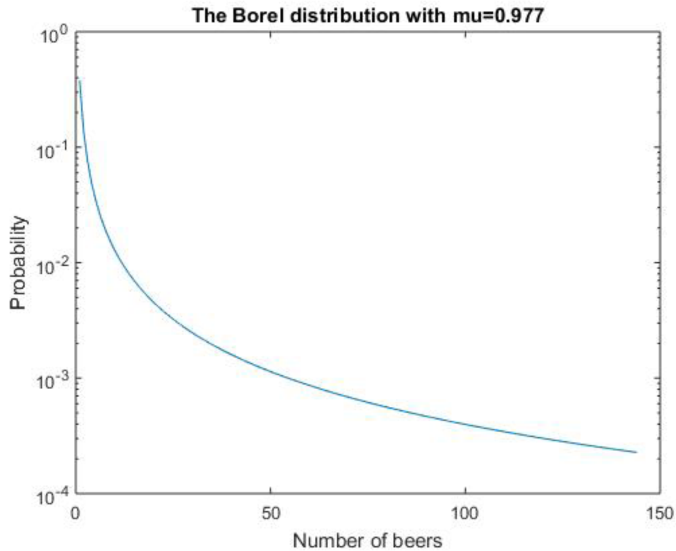


Figure 2: a comparison. Above is a visual representation of our empircal data, below is our fitted Borel distribution.

Global hands-on Boreling: *reële analyse*

Such a visual resemblance is of course cool, but we also want some concrete theoretical underpinning to really understand what is going on here. Let us start by giving the Borel distribution formula:

$$P(X = n) = \frac{e^{-\mu n}(\mu n)^{n-1}}{n!}$$

In which X is a discrete variable, ranging over the positive integers. Note that it is a prerequisite that at least one beer is consumed. The Borel distribution is therefore to be applied to days at which there will be definitely be drunk. Completely alcohol-free days, which are scarce *überhaupt*, are neglected. Obviously, the distribution's behavior depends on the parameter μ, which ranges between 0 and 1. If μ is zero, this means that every day precisely one beer is drunk. The other extreme, when μ is one, yields a far more real consumption. Globally, meaning all members and all time combined, we turn out to be somewhere inbetween: 0.977. This is calculated by a so-called Maximum Likelihood Estimator, that was first found by Mark. *Hoi*.

$$\mu_{MLE} = 1 - \frac{1}{\bar{x}}$$

In which $\bar{x}$ (x bar) is the average number of beers consumed on a day, if that number is positive. This gives us a majestic and surprisingly compact conclusion:

$$X \sim Borel(0.977)$$

Local analysis

The fact that our global drinking behavior confines to Borel may suggest that similar results hold for local data: pertaining to only one person, or a short period of time. Over time, it turns out that μ is slightly increasing, but the Borel distribution shape is approximately conserved. Taking only one person, or even a group of people is an entirely different story. There exist members that hardly ever drink one beer, and have a far higher mean. Your own beer consumption distribution is something very personal: cherish this. The global distribution is mainly due to the varying number of members (drinking) in the Francken room. This also gives us a Borelneck: there's a limit to how many members fit in (and around) the room. May the Feringa Building change this.

Further reading

I've recently written a more elaborate article on this subject for the course Mathematics and its Environment, which you can request by e-mailing the board.

If you want to know more about Émile Borel and his alleged cousin, the fellow mathematician Armand Borel (and all the puns related to their surname), read my blog on the Francken website. If you have any original thoughts on the subject, don't hesitate to contact me!

References

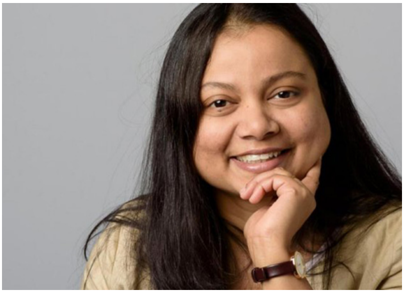
[1] http://borrelcie.vodka/2/public/#/stats

[2] Lustrumboek, 2014

Spintronics on a dime

By Prof. dr. T. Banerjee

What do Spin and Spintronics offer? Soon the quantum enigma called 'spin' will celebrate its centennial following its observation in the canonical Stern-Gerlach experiment back in 1922. Ever since the prediction and explanation of the 'classically indescribable' intrinsic property of the electron - the spin - it has been used to understand physical concepts in magnetism, optics, atomic physics, quantum electrodynamics and applied to medical imaging, information processing, hard disk industry and the like. In fact, utilizing the spin property of an electron has led to a thriving branch of science and technology known as Spintronics, that was aptly awarded with the Nobel Prize in 2007, a decade after its discovery by Albert Fert and Peter Grunberg. Spintronics today encompasses several new phenomena brought about by



magnetic field, spin polarized current, electric field, spin orbit coupling and topology in diverse classes of materials and their heterostructures ranging from metallic magnetic multilayers, ferrimagnets, antiferromagnets, magnetic insulators, topological insulators, etc. Spintronics utilizes the spin of the electron in addition to its charge for designing non-volatile memory devices. These devices operate at different length

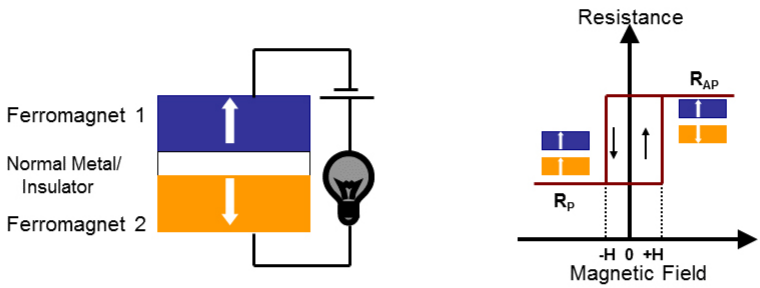


Figure 1: Left: giant/Tunneling Magnetoresistance. Right: device and the variation of magnetoresistance.

scales and, most importantly, retain their fundamental properties when downsized to the nanoscale, unlike that in conventional electronics, and this has been a primary reason behind its extraordinary success in new technological applications and system level integration with CMOS. The new class of magnetic memory based on spin transfer torque commonly known as STT-MRAM (more precisely MRAM embedded integrated circuits) is all set to for commercial production in early 2018. Such has been the technological viability and economic success of Spintronics that it gives a whole new meaning to be 'on a dime'.

My introduction to Spintronics was at the Francis Bitter Magnet Laboratory, MIT, USA, in the group of Prof. J. S. M. Moodera who is credited with the first observation of large room temperature magnetoresistance in magnetic tunnel junctions. We explored the efficiency of such device performance to irradiation environments, as these are the key components used in spacecrafts. Since then, my research over the last two decades has significantly concentrated on investigating new material and devices for studying unexplored spin transport phenomena for both electron spin and hole spin transport.
The basic building block of a spintronic device comprises of a trilayer structure comprising of two ferromagnetic layers separated by a conducting spacer layer and known as the spin valve as shown in Figure 1. The device response known as the giant magnetoresistance (GMR) is defined as the change in resistance when the magnetization of one of the ferromagnetic layers flips,

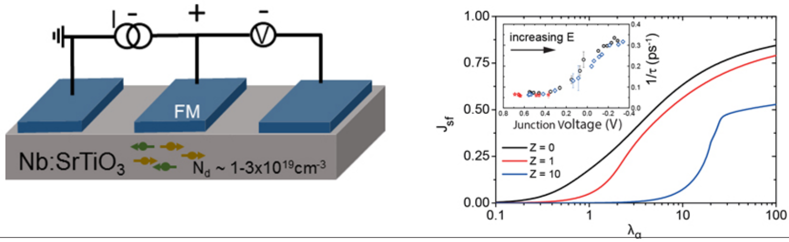


Figure 2: Left: Spin injection interface of a ferromagnet (FM)/oxide semiconductor. Right: The variation of the spin lifetime (both experimental and from theory) at room temperature in an oxide semiconductor. [1]

with respect to the other, thus defining a clear parallel and antiparallel state and a magnetoresistance, that is the normalized difference of the two resistance states. Such GMR devices have been used to explore new phenomena in spintronics and other upcoming architectures. The other popular device in Spintronics, known as the magnetic tunnel junction (figure 1), is also based on a trilayer structure that uses a thin tunneling barrier such as AlOx, MgO sandwiched between two ferromagnetic layers instead of the conducting spacer in GMR devices. Here too the magnetoresistance change is recorded as a change in the magnetization orientation of the two ferromagnets. For practical implementation, quite often the bottom ferromagnet is pinned by an (synthetic) antiferromagnetic layer.

Just as C in CMOS captures the transport of holes in conventional CMOS devices our first work concentrated on studying C-SPIN (Complementary Spin) devices, integrating spin valves (magnetic trilayer separated by a conducting metallic layer) on p type Si. We explored such devices at the nanometer scale using a versatile technique of Ballistic Electron(hole) Magnetic Microscope and found that hole spin transport parameters are governed by phenomena that are different from that governing electron spin transport. One of our major findings was that spin dependent transport with holes was related to the spin asymmetry (the ratio of majority spins to minority spins, where majority and minority spins refer to those spins that are oriented along the direction of the magnetization in the ferromagnets, and thus quite different from majority and minority carriers used in electronics) of the group velocity of the hole spins rather than the spin asymmetry in the spin lifetime. A large magnetoresistance was observed, comparable to what was observed for electron spin transport and proved counterintuitive to what was expected from simple electronic band structure analysis.

> *Spintronics has never ceased to surprise - both from the discovery of new phenomena as well its potential in defining new applications.*

Since 2009, I work at the Zernike Institute for Advanced Materials. My group Spintronics of Functional Materials works on material interfaces and their devices, which are ideal platforms to investigate new phenomena in spintronics. The material platforms that we employ are of three kinds: perovskite oxides integrated on an oxide semiconductor, topological insulators and graphene/two-dimensional materials on an oxide semiconductor. The emergent functionalities that we have found over the years are related to the breaking of inversion symmetry at perovskite surfaces and its stabilization at heterointerfaces - functionalities that are not found in their bulk. When combined with spin-orbit interactions, this led to new mechanisms to control spin states in devices, such as electric field control of electronic devices, voltage control of magnetic state as well as design and control of new spin textures such as magnetic bubbles, domains and skyrmions.

Spinning the oxide interface

In the family of perovskites, complex oxides are particularly attractive due to the abundance of different ground states such as ferromagnetism, ferroelectricity, insulating, semiconducting and superconducting in the same family. Integrating these materials and engineering heterointerfaces made it possible to tune the interfacial electrostatics so as to inject and detect spins while manipulating its transit across an unconventional oxide semiconductor (Nb doped $SrTiO_3$) using an electric field. This finding is unlike that demonstrated, so far, using conventional semiconductors. Such interfaces host spin orbit fields (Rashba), which, assisted by the non linear dielectric permittivity intrinsic to $SrTiO_3$, allows for its control by the inbuilt electric field at such heterointerfaces. This has paved the observation of new effects such as the tunneling anisotropic magnetoresistance in coexistence with

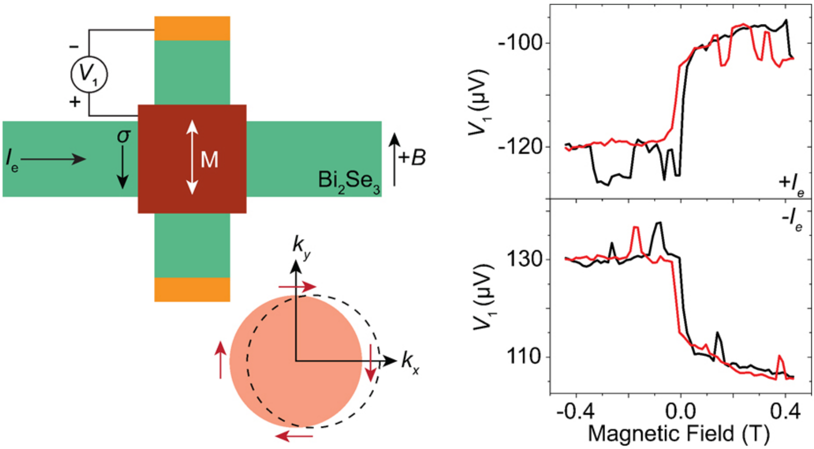


Figure 3: Left: Topological insulator (Bi_2Se_3) device geometry. Right: The spin momentum locking detected.

electroresistance, a coupled phenomenon, which has important bearing for implementation in spin logic and neuromorphic computing architecture, which we are currently investigating.

Wonder Material: Topological Insulators

My group has actively worked on a new wonder material in spintronics known as the topological insulators. These materials are characterized by an insulating bulk and metallic surface states crossing the bulk band gap, and such surface states are proposed to be protected by time reversal symmetry, making them robust against disorder and endowing them with a unique property of locking the spin and momentum of the charge carriers. This means that in principle the charge carriers can be 100% spin polarized, thus offering new prospects in spintronics. What we experimentally found out is the successful demonstration of spin momentum locking in topological insulators of Bi_2Se_3, but additionally addressed the extreme caution needed to interpret the surface states - both their origin as well as their properties - before these can be implemented in active spintronic devices. For a complete understanding of these materials, harnessing and coupling the relevant conducting pathways responsible for spin momentum locking is needed as well as new device designs that connect the bulk insulating property of these materials with the conducting surface states.

Integrating flexibility at new interfaces

Dirac materials such as graphene and other two-dimensional materials offer a flexibility similar to complex oxides, by offering a suite of physical properties by tuning interfaces or material composition. Thus integration of such material systems with complex oxides provides an active playground to unearth the vast potential of both these material systems. We have observed an unconventional dependence of spin and charge transport in graphene when interfaced with $SrTiO_3$, which we believe has multiple origins - in the local electrostatics modulation of the polar domain walls when $SrTiO_3$ undergoes a phase transition, as it is cooled, as well as in the tuning of the temperature dependence of the dielectric permittivity at such interfaces. These results are just the start and we believe that this has much to offer in the future.

Spintronics has never ceased to surprise - both from the discovery of new phenomena as well its potential in defining new applications. An important frontier in sight for further implementation of Spintronics is in the Internet of Things. Strengthening its connection with society through diverse sectors from health care to information technology is a key to creating a secure and promising future. Spintronics nurtures innovation and creates new opportunities and relies on the future motivated young researchers to carry it forward.

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Black or White

By Jasper Pluijmers

After Albert Einstein presented his general theory of gravity in 1915, which included the famous Einstein equations, scientists tried to find solutions to these equations. A few months later Karl Schwarzschild found his first solution of the gravity field around a point mass. An interesting phenomenon occured at a certain distance from the point source, certain terms in the solution become singular. It took a long time for physicists to explain these singularities. In 1885 it was correctly identified by David Finkelstein as an event horizon, a region in space where causality only flows one way. It took until 2015 to finally observe a black hole, when the effect of gravitational waves due to the collapse of two black holes was measured at LIGO. Black holes are quite simple objects, the only properties they can have are mass, charge and angular momentum. As a consequence, two black holes that have equal mass, charge and angular momentum are indistinguishable from each other. So let's look at one such black hole.

Event horizon, a point in time

When I say causality only flows one way it means that events outside the horizon could influence an event inside it, but not the other way around. To visualize this we can look at the light cone, which is the region in spacetime influenceable by an event. This is easy in flat, Minkowski, spacetime: in the diagrams you remember from special relativity this is just a 45 degree cone.

To remind you, in Figure 1, B is casually connected to A while C is not and every point within the light cone could be a possible future for the particle. Now going back to

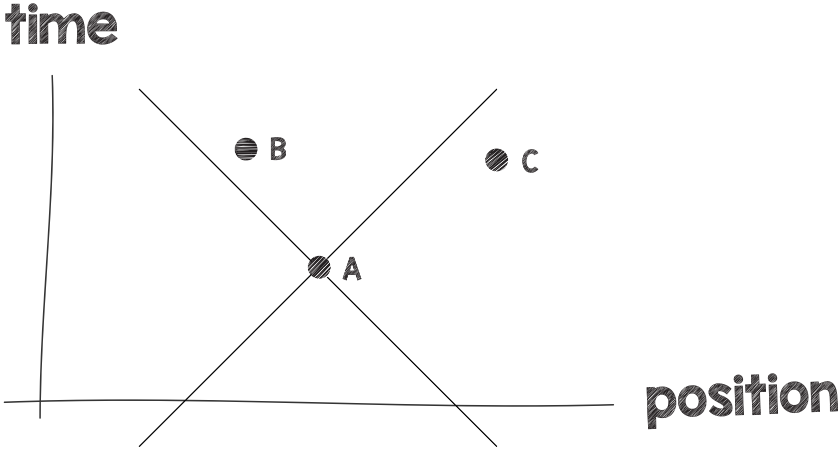


Figure 1: A spacetime diagram with 1 spatial dimension.

our beloved curved spacetime it will be less simple, see Figure 2. A particle falling into a black hole will see its chances to escape diminish until, when he crosses the event horizon, the edge of his light cone is not pointing away from the black hole anymore. As soon as a particle crosses the event horizon, all possible futures of this particle (the region inside its light cone) are towards the singularity, therefore you could think of the singularity as a moment in time instead of a point in space. To visualize this we are going to look at Figure 2.

Singularities

A problem arises in this solution, the Schwarzschild metric: it has a singularity at $r = 0$ and at the Schwarzschild radius, the event horizon. This means that the solution at $r > r_s$ is disconnected from the solution at $r < r_s$. This second singularity, luckily, appeared to be non-physical, a change of coordinates removes it from the solution. An example of such coordinates are the Eddington-Finkelstein coordinates. By analytically extending the Schwarzschild solution it is possible to connect the two regions and find a single solution valid in the region $0 < r < \infty$.

Maximal Extension

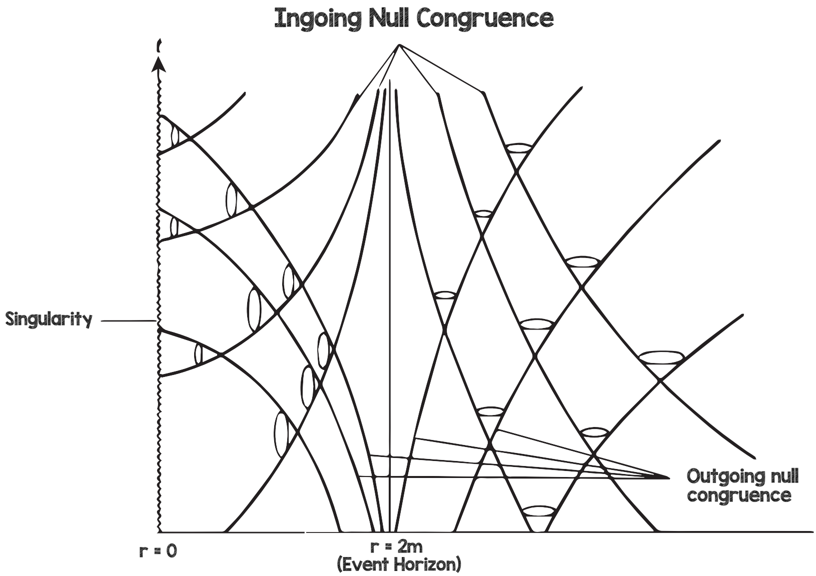
Now that we have removed the coordinate singularity, you must immediately think: 'can we extend the solution even further?'. The answer is yes, by imposing certain properties on how particle paths behave a maximally extended solution was found by Kruskal. This extension gives rise to some interesting new ideas, for which we are going to look at Figure 3. The diagram consists of four regions. The universe, on the right, is our normal universe. Just as in our previous solutions, particles can flow from the universe into the black hole, but can never return. The more interesting part is the other side of the diagram.

White holes

At the bottom we see what is called a white hole, it is best described as a 'reverse black hole'. Instead of causality flowing into a black hole, at a white hole it can only flow the other way. Therefore these two different singularities are also sometimes labeled as 'future' and 'past' singularity. No evidence of real white holes has ever been found, but some interesting proposals have been made. A problem is of course that if a white hole exists it should very quickly stop existing due to it running out of stuff to eject. The first thing that comes to mind is that it shares a lot of properties with the Big Bang, which is a point in time where everything in our universe origins.

Another candidate white-hole was proposed in 2011, a gamma ray burst. Gamma ray bursts are the biggest explosions we have observed in the universe with no definite cause found. Therefore it would not be that far-fetched to see them as the birth

Figure 2: A spacetime diagram of a Schwarzschild black hole.



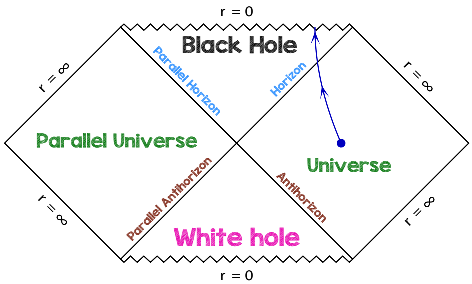


Figure 3: Diagram of the extension of a Schwarzschild blackhole.

and death of a white hole.
The last part of this diagram is the 'Parallel universe', it is mathematically possible to have a whole other universe also connected to the two holes. We could, however, never contact this other universe. We cannot move into the white hole and if we would go into the black hole, we could never get out on the other side. If by pure chance you and your parallel self on the other side would jump into the black hole at the same time, you might see each other get ripped apart by tidal forces. Unfortunately there is no way to communicate this back to one of the universes so you will know that even in death you are useless.

More universes equals more better

So the extension of the Schwarzschild solution is crazy, it gets even more crazy when you consider rotating and/or charged black holes. Apart from the double event horizons or spherical singularities, the maximal extension of a Kerr (rotating) black hole gives rise to an infinite amount of universes, as seen in Figure 4. The implications and interpretation of unlimited (parallel) universes are left as an exercise to the reader. *Bij deze rust de theoreet zijn koffer.*

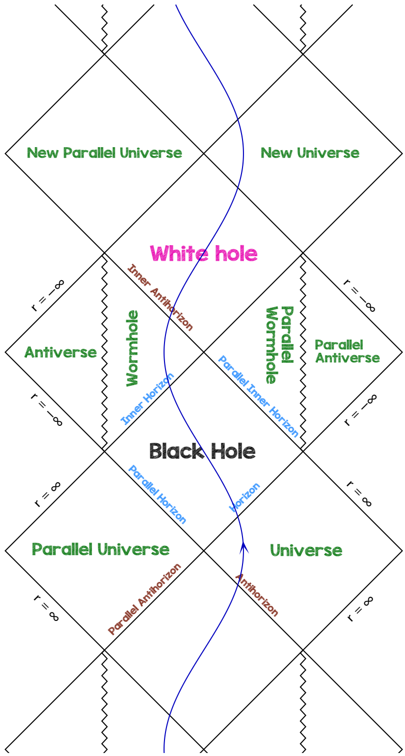
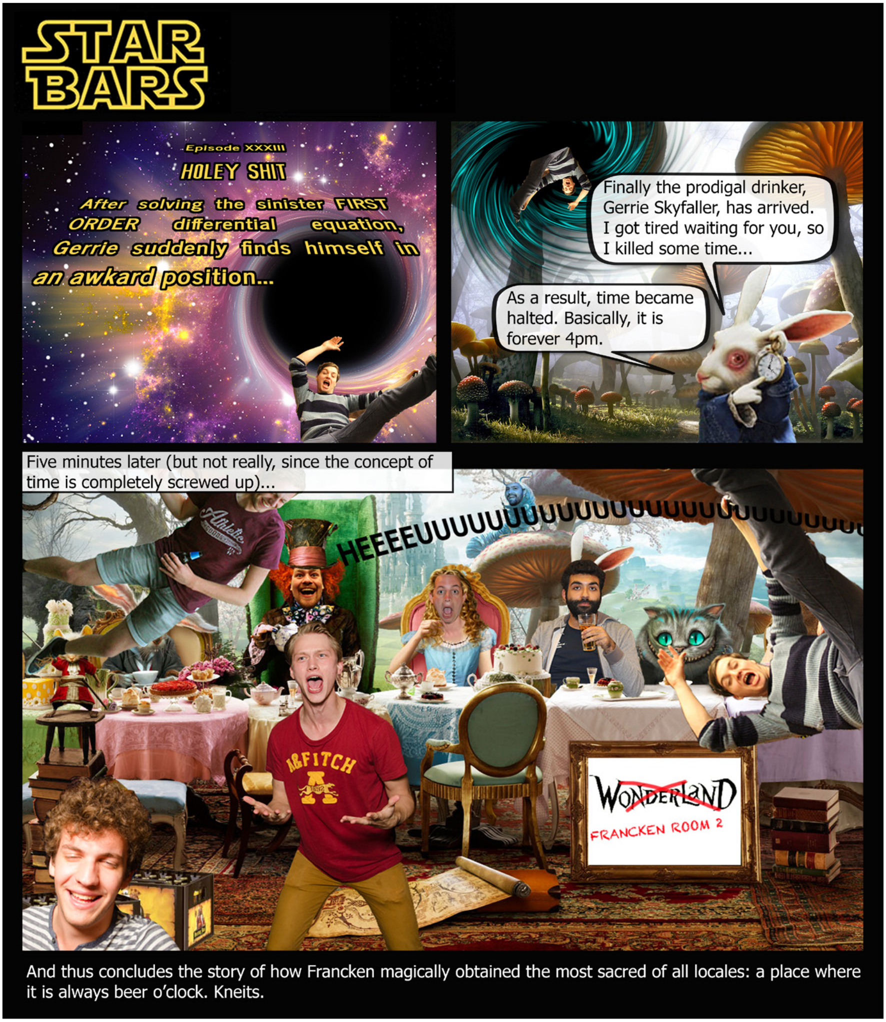


Figure 4: Diagram of the maximal extension of a Kerr blackhole.

Comic

By Kathinka Frieswijk



About humming bees and humming tops: 40 years professorship in Groningen

By prof.dr. Jeff Th. M. De Hosson

On **October 6th**, 1977 I was appointed to the chair of Materials Science-Applied Physics (as today we would call 'hoogleraar 2/A'), a Crown-appointment, in the best of Dutch academic traditions by Royal Decree signed by Her Majesty Queen Juliana (Figure1). Therefore, the same date this year marks my 40th anniversary as Professor active in scientific research. My Chair position was later promoted and upgraded by the Executive Board of this University, i.e. after retirement in 1984 of the founding father of Engineering Physics, Professor Jan C. Francken (1919-2007), to 'Central Chair of Applied Physics Groningen', 'hoogleraar 1/B'.

Unfortunately, the system of Crown appointments of full professors (and well paid through the Ministry in The Hague as a left-over from the Napoleonic times) was abandoned by Her Majesty Queen Beatrix

Besluit van
6 oktober 1977

nr. 101

Wij Juliana, bij de gratie Gods,
Koningin der Nederlanden,
Prinses van Oranje-Nassau, enz., enz., enz.

Figure 1: letter from H.M. the Queen.

around 1986. The main reason was that universities boosted for their own 'independent' authority & power, whatever that may mean, but independent of 'The Hague'. So most likely I am the very last prehistorical Dodo left-over Crown appointee myself, still in active service in this Faculty and School of Physics/ Zernike Institute for Advanced Materials. On the occasion of the 40th anniversary the Board of Francken approached me for a brief flashback and here it is.

When working in USA as a postdoc in Northwestern Un Chicago-IL and Berkeley-CA (Lawrence-Berkeley Natl. Lab) in the seventies I was approached by the Faculty, ruled by Dean Jan Borgman, to open new vistas in Materials Science. In particular, I was asked to set up a new (electron) microscopy lab and decided to accept a position as Chair in the Department of Applied Physics after turning down offers from Philips Nat. Lab. Eindhoven to join Andries Miedema's group as well as an attractive invitation from Geert Dallinga Shell Research KSLA-Amsterdam.

Why did I turn to Groningen, you may ask? In the seventies my field of research stood on the threshold of something really new: i.e. on the development of electron microscopy to solve materials' problems and accepting the offer to build up a new materials science group around electron microscopy was very appealing. Furthermore, Groningen had a great tradition with Frits Zernike (1888-1966), Groningen's Nobel laureate for Physics (1953) on (phase contrast optical) microscopy. Even today some aspects of high-resolution imaging electron microscopy are built on the same principles of weak-phase contrast optical microscopy invented by Frits Zernike.
Another reason of accepting the offer from this University was that 'Engineering Physics' at a classical University like Groningen was also a very intriguing and novel concept

Figure 2. (a) the author in 1977, (b) same author in 1977+40.

Figure 3: obligatory literature for Groningen students.

to me: no other classical general university in the country, e.g. Leiden, Utrecht, Amsterdam, offered an Engineering Physics degree (with the appropriate Nat. Ir title). But was it really such a new catch? Much later I found out that the actual start of Engineering Physics in Groningen holds its own, very unique place in history since already in 1827 engineering was taught to a couple of students of the *Academia Groningana*.

The start in 1977

In 1977, Berkeley-California was still in the excited state and offshoot of the flower-power culture, which started already in the sixties in California (San Francisco, in particular the Bay Area with Berkeley) but during my own stay, flower-power became transformed to the 'hippie' counter culture of the seventies. Even myself I looked, like all other fellow postdocs, rather as a 'hippie' (Figure 2a) and quite different from the year 1977+40, Figure 2b. You can imagine how big the first-order phase transition was when I arrived in Groningen!

One of the first things I did when coming to Groningen was to read a couple of books by Willem Frederik Hermans, very amusing and still (partly) full of clean-cut judgements about the 'University of Paterswolde' under the 'Barbarossa tower'. If you have a chance and time, you should read all three (Figure 3).

It goes without saying that there are so many differences between California and Groningen but a few were noteworthy. Interestingly the entire structure of our School of Physics in Groningen was neatly arranged in 1977 and far less complicated compared to the current, very complex situation 40 years later of so many Tracks in physics and dispersed over 4 different research institutes. The 'techies', as I called us, resided in Nijenborgh 18 (T.F.L.-Technisch-Fysische Laboratoria), the theoreticians in the WSN building and the core of Experimental Physics remained, until 1990, when I was Dean of Physics myself, in the Westersingel Complex, including de Melkweg ('Het Kasteel').

Also I found it intriguing to see that each location had its own 'Science Pope' (Jan Francken for the 'techies', Nico Hugenholtz for the theoreticians, Ad Dekker (1919-1994) for solid state physics, Jan Kuiper (1924-2004) for Biophysics, Rolf Siemssen for KVI and definitely our Super-Pope was Hendrik de Waard (1922-2008) – honorary member of FMF – covering the Westersingel Complex) (see Figure 4), but interestingly enough also each physics location had its own St Nicolas! Obviously, due to the provocative character of our notorious sorehead 'zeurpiet-se' Sheperd of the United Nations pouring oil on to the flames, I will not go into details about our learned black knaves — *Zwarte Pieten* — who assisted St Nicolas in the past at these various Physics locations!

The total number of professorial chairs in physics (including KVI) was small (around 10) leading to a transparent and (although regrettably much too long spread over 5 locations) reasonably efficient organization of 'vakgroepen' with well–defined respon-

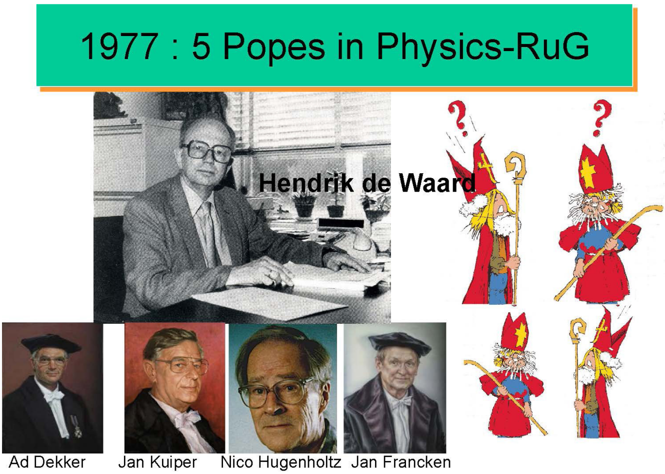


Figure 4: 4 popes and 1 super pope in the School of Physics of 1977.

sibilities and duties for everyone. Administration and administrators were minimal. Rather, the individual professors were in charge, highly respected and running their own business in education, research and administration. Because of the enormous explosion in 'complexity' in the nineties, inside as well as outside the university, this is all gone and will never come back again. Crown appointed professors got the trust *right from the start*. That was a very attractive point and also very important for exploring new avenues in science. However, at present the great variety of various levels of professors in Groningen *may* receive 'trust', yes indeed, but only several years *after appointment* and that makes an essential difference.

Luckily enough, invariant over the years was the passion for education and research. The enthusiasm of all of us in MK remained over 40 years, dedication was abound and the scientific intellectual inspiration of the 'techies', from students to (crown) teachers grew.

I remember that following the introduction of the 5-day working week, according to Hendrik de Waard, it was not a good idea to take the Saturday free, but actually - like the rest of the weekend – to work undisturbed in the laboratory. Also we were convinced that the starting time in the morning has to be evaluated thoroughly and scientifically, i.e. the time of going to bed, and to get back to work in the next morning had nothing to do with each other. I guess we called those two different 'quantum states' fully *uncorrelated physical events* (we respectfully ignored quantum states of 'entanglements').

Perhaps it is because we as 'techies' were in a diaspora, on the tundra and prairies/pampas of Paddepoel, but I really think the T.F.L. was the most intense of the physics community. This is supported by the renowned 'T.F.L. Bistro' dinners prepared by scientific and supporting staff.

Due to the administrative scale since the advent of wider-reaching FSE in the 1990's, enforced by the Executive Boards of University and our own Faculty, this 'intense physics community' all became past and passé. Best is that my materials science class, showing *'smaller is stronger' in materials*, should be offered as a mandatory course to administrators! What do you think?

A couple of snapshots over 40 years

After we had built within MK our microscopy labs solely on external funding (at present we have 8 different electron microscopes up and running, managed and kept operational at a high level by David Vainchtein and Vašek Ocelík) we were also able to complete the triangle of materials 'processing- characterization- properties' via high-power lasers (Vašek Ocelík) and physical vapor deposition techniques (Yu Tao Pei). The fundamental ideas in the background guiding our MK research over the years is that physical properties of materials are determined by dynamic, non-linear effects of defects, being not in thermodynamic equilibrium, at different time and length scales. Examining intrinsic versus extrinsic size effects at small (nano-) scales is currently a topic of our rigorous investigations. An overview of our research and breakthroughs can be found on our web site *http://materials-science.phys.rug.nl/* and in the long list of more than 1100 publications.

It is not the place here to dwell too much on details of our discoveries and breakthroughs in 40 years but one example is illustrative when combining physics and engineering. As we all know, a new field of science, called "microscopy" was opened up by Galileo in 1609 and the discovery by later scientists, in particular Antonie van Leeuwenhoek in Delft, of the existence of bacteria prompted the sterilization of surgical equipment taken for granted today, saving millions of lives ever since. Needless to say that optical microscopy through Frits Zernike has made a spectacular contribution to mankind but that is equally true for electron microscopy in the development of new materials. *'Seeing is believing'* that sounds all attractive. However, there exists a big '…BUT…' since there is a serious problem with microscopy, namely: any micrograph provides only a *projection* of an object in two-dimensions although we are interested of course in an object defined in three dimensional space (3D). Although there are several ideas in literature to tackle this issue, they all rely on information about the microscope itself and suffer from severe calibration problems.

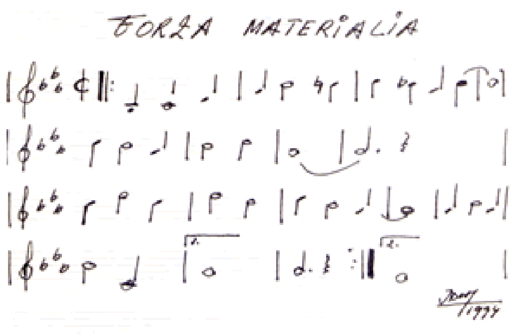
In contrast, in MK we have designed – in particular pushed by the best, out of my 83, MK PhD student ever, Diego Martinez-Martinez, a novel procedure to obtain 3D surface reconstructions from electron microscopy images acquired at different angles. The main advantage is that *no a priori information* about the imaging equipment is needed, and therefore complex calibrations of the equipment are bypassed. The invented new methodology can easily compete with existing methods as far as resolution is concerned (such as atomic force profilometry) and *importantly put aside these* existing methods in a spectacular way because of the combination of resolution and analytical (chemical & crystallographic) capabilities of electron microscopy. The latter is very relevant since modern science & technology depends critically on the availability of advanced materials. Tailoring these materials with a desirable set of chemical & crystallographic properties over various (microscopic) length scales is the dream of materials scientists. The method was patented in 2015, with patent number WO/2015/185538,EP14170815.6, PCT/EP2015/062231 and published in various scientific articles.

Over the 40 years of professorship, together with my loyal collaborator Paul Bronsveld we made besides new science also 'special products', i.e. special lyrics for each

MK PhD graduation party where I had to play the piano with great joy, starting with the well-known 'Forza Materialia' (Figure 5). For details see our web site: *http://materials-science.phys.rug.nl/index.php/scientific-publications-phd-thesis-and-awards/phd-theses*.

Yes indeed, 40 years was hard labor but it provided a lot of satisfaction and credits from the international community of my peers, not from the locals though, to all of us in MK. How hard is hard, you may ask? Around the start of the MK group in 1977 the average output was 0.1 PhD

FORZA MATERIALIA



what good is having a doctor's degree
come see the emka play
only a cabaret, old chum
come hear what we've to say

put down your talking, your books and your drinks
time for a little sketch
only a cabaret, old chum
m a t e r i a l i a

start by admitting from student to doc
isn't that long a way
only a cabaret, old chum

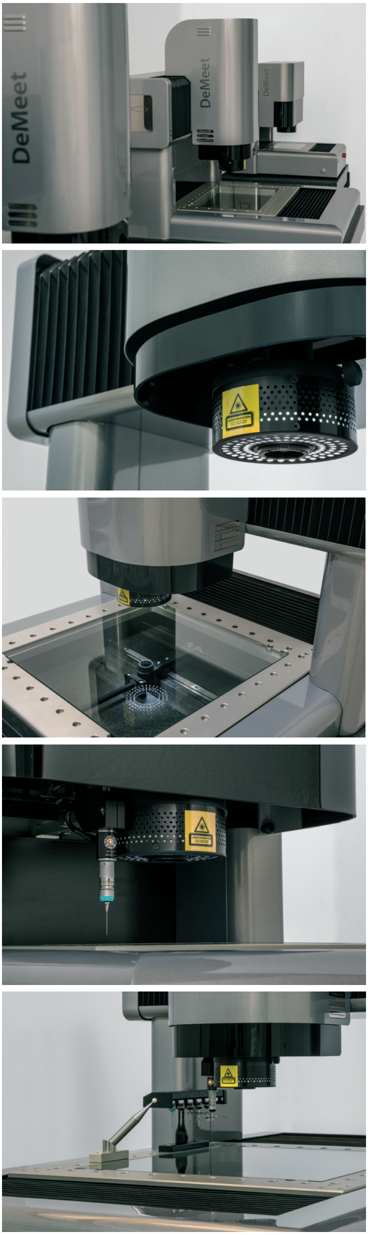
let's look what we've
let's hear what we've
let's see what he's to say

Figure 5: MK Choir performance of Forza Materialia.

graduation per professor per year. Today, the Faculty expects that we should realize 1 PhD graduation per year per permanent staff member so as to stay out of the red and in the black numbers. We are not getting there yet, but clearly the demand on us has increased 10 fold, and that with much less technical support (also 1 order less), so in fact 100 x, and including the growing numbers of students, say we have to work 1000 x harder since I started in 1977 (i.e. a 0^e order approximation over a period of 40 years; the analysis is quite reasonable since 'efficiency' did not increase 3 orders of magnitude and we did not become 3 orders of magnitude smarter but far less).

Invariant of running a very successful MK group over 40 years, equally successful was T.F.V. 'Professor Francken'. '*Francken*' became a *new phrase* in the University Dictionary of the Faculty and I am proud of it. Almost every day I hear students saying: "see you at *Francken*", "Let's meet at *Francken* for lunch" and that is really a great sign. '*Francken*' has not only become a mature and a professional organization but something very special indeed because every student from Groningen reading Engineering Physics generates beautiful memories, develops every respect for each other's talents and new ideas, gets inspiration and discovers oneself. That is something for many people, including myself, within the university to enjoy.
Therefore in 40 years of professorship in applied physics, on behalf of Engineering Physics Groningen many of my thanks are owed to the T.F.V. 'Professor Francken' club; yet it is exceptional that in a time of credit-related grants and loans, performance grants, loan schemes, binding study advice and discussions about (financial) efficiency, again so many enthusiastic students are found with their heart in the right place for Engineering Physics in Groningen.

To outsiders, 'science & engineering' may sound a rather boring and undercooled activity, but for me over 40 years in science had everything to do with emotions, to explore scientific ideas, write many, many papers , write many, many proposals for grants, funding accepted by the community… for me it was also emotional, i.e. for the experts among us: a state of '*plane stress*' as well as '*plane strain*'. Besides having my own vision on microscopy for materials science, i.e. as I used to say '*gaining sight after being blind*', I have loved the intellectual scrums and I am planning to enjoy it in the years to come, in an Academia environment I would characterize as very non-linear, far from thermodynamic equilibrium, never in any ground-state, with many international intellectual humming bees and humming tops I was privileged being part of.



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Aangezien we onze activiteiten uitbreiden, zijn we continu op zoek naar enthousiaste medewerkers om ons team te versterken. Als jij wilt werken in een bedrijf dat mensen met ideeën en initiatief waardeert, dan is Schut Geometrische Meettechniek de plaats. De bedrijfsstructuur is overzichtelijk en de sfeer is informeel met een “no nonsense” karakter.

Op onze afdelingen voor de technische verkoop, software support en ontwikkeling van onze 3D meetmachines werken mensen met een academische achtergrond. Hierbij gaat het om functies zoals ***Sales Engineer***, ***Software Support Engineer***, ***Software Developer (C++)***, ***Electronics Developer*** en ***Mechanical Engineer***.

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