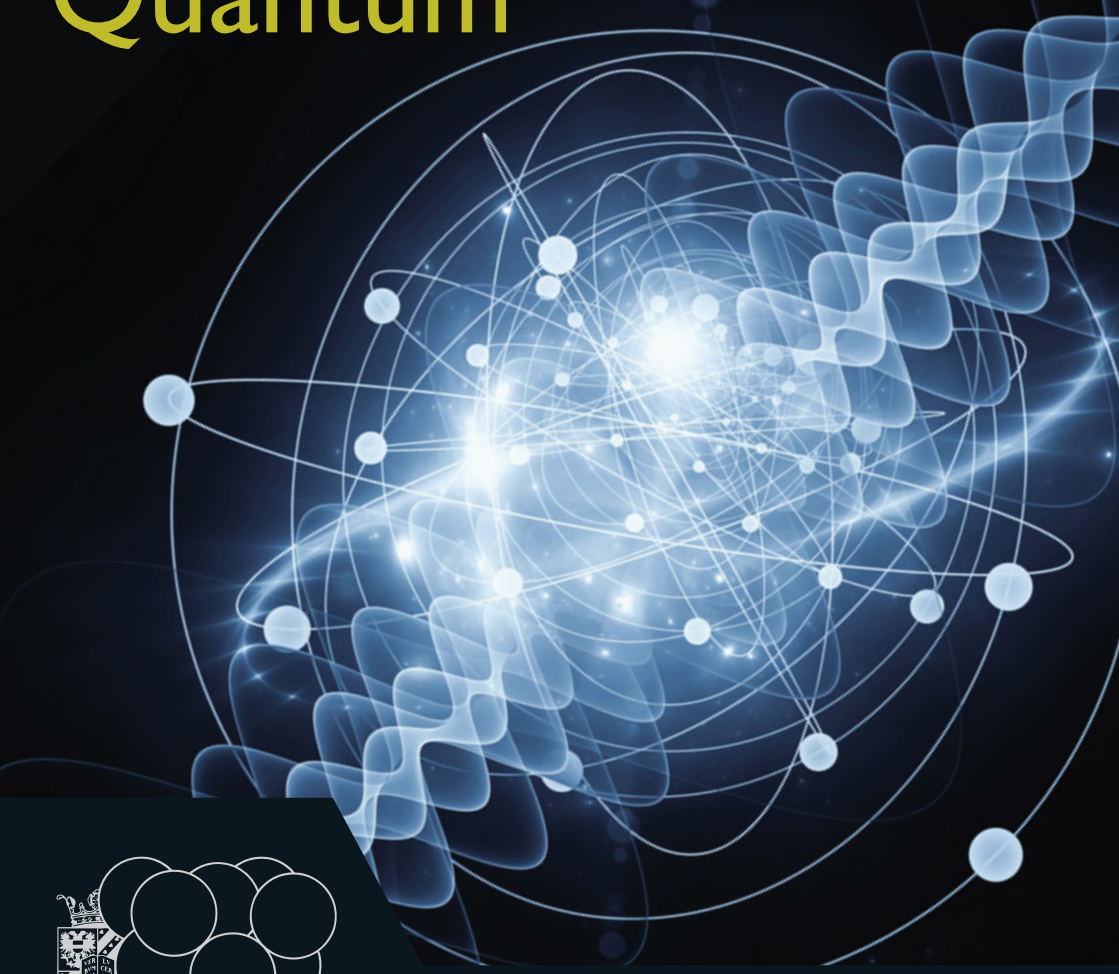
Quantum Gravity
Quantizing the theory of gravity

Francken Abroad
Life in the city of Valencia

The Green Future
Improving the future of humanity

Francken Vrij

Quantum



20.2 Quantum

De fiscalist in jezelf ontdekken

Ook dat is #werkenbijpwc

Jij? Welkom bij PwC? Nou en of! Om lastige fiscale vraagstukken op te lossen hebben we alle denkbare talenten nodig. Intelligente, ambitieuze mensen uit verschillende studieachtergronden en disciplines. Die anders kijken. Andere vragen durven te stellen. Alleen zo, geloven wij bij PwC, komen we tot nieuwe, verfrissende oplossingen voor onze klanten.

Ben je uiterlijk 1 september afgestudeerd, heb je goede studieresultaten en een ondernemend CV én wil jij aan de start van je carrière alles uit jezelf halen? Meld je dan nu aan voor het Tax Traineeship of een van de informatiesessies op ***werkenbijpwc.nl/taxtraineeship***

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The opportunity of a lifetime

Colophon

Editorial

The theme of this Francken Vrij is 'Quantum'. Quantum for me means really trying to not make a cliché joke about superpositions, cats or dualities (although the fact that I already spent a Francken weblog doing exactly that helps me in retraining myself).

I always wonder if anyone ever reads this, that's why I am going to do an experiment. The first 10 people who call me out on this gets one free beer at a 'borrel' of your choice. Because now you know that you are gonna have free beer, this Francken Vrij is gonna be extra nice, Have fun!

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Edition 20.2

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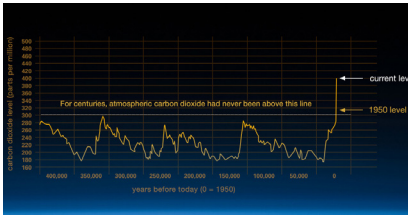
Xu Yang

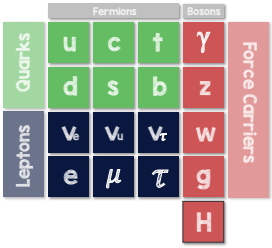
Xu Yang from the nano devices group Tells about how he working on a better future for humanity.



32 The Theorist

Remko Klein

General relativity is a really nice theory for gravity, but it doesn't compute with quantum mechanics. How do we solve this?



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Nikki Arendse

Nikki was in Valencia, Spain for 6 months. She tells us about her experiences in both the student and social life.

29 Puzzle

Steven Groen

Entangled answers make for one of the most original puzzles in the history of the Francken Vrij, can you solve this?

Chairman's Preface

By Jelle Bor

As the academic year evolves I see that our members grow in their intellectualness. Every step they take is a new step towards their career/future, which for some is still very far away and for others very near. I am glad that we, T.F.V. 'Professor Francken', have a share in this social, career and study related growth, because being a student is a very important phase in life. Now, let us take one step backwards, one that's complex. That it's a complex one should not be a surprise because the theme of this Francken Vrij is Quantum.

I'd like to talk about the so called quanta of life. We, as human beings, can see that everybody goes through different phases of life. I presume I have passed childhood, puberty and I'm currently passing though the young-adult phase. When I think about these different phases in a purely observing way, two things come to my mind. First of all, mankind itself came up with these phases, which is, just like placing things in boxes, natural. Secondly, I am wondered whether I'm really in the young-adult phase, or not? Maybe someone else will think differently about the phase of life I experience. Someone older than me can think I'm not yet in the young-adult phase and someone younger than me can think I'm already in the adult phase. I don't know what the right way of thinking is, but I'm almost certainly in both phases at the same time. When I have a conversation with a certain person, I will put myself in a certain phase of life. I think however that it's only natural that people assume a certain personality at the moment of social interaction.

Does that sound familiar? Just like a particle in your quantum course. A quantum state is just like a human being: before interaction it is in multiple states and when interaction takes places it assumes only one state. Let's try to fit another quantum concept in the contemporary life of a physicist. The Heisenberg uncertainty principle can be applied to this magazine. When you are very enthusiastic about the text you are reading, you have a lot of energy, but the time you thought it took you to read it, would be very short. Of course this also works the other way around, but let's not emphasize on that. I hope that after reading this Francken Vrij you will have learned more about quantum and, more importantly, you'll have the feeling it took you no time at all. Time flies when you're having fun!

News of the Association

With events coming and going, the Buixie to Norway nearing and our board year passing, time seems to be going faster than ever as I write my second 'News of the association'. There have been plenty of borrels, lectures, dinners and other events of which a small selection has been made below.

By Max Kamperman

Practice sessions

At the point of writing this article Francken already put together 9 practice sessions this academic year and there are still a lot to come. Not just the freshmen left our sessions well-informed, but also second year students got the benefit of extra exam preparation. The newly organised sessions included Quantum Physics 1, Statistical Physics and more.

Tour de Francken

We, as Applied Physicists, tend to express that we enjoy building things and not just with duct tape. A proof of this is the entirely new timing system for this year's edition of the Tour de Francken, which probably needs no explaining on its own. Built from scratch, the new system is better, more durable, better looking and helped make the Tour a success again. Six teams (and a spectator team) competed in a tense match to go home in one of the prestigious jerseys.

Excursion Philips

A delegation of Francken members boarded their vans on a February morning for a visit to Philips Consumer Lifestyle in Drachten. The Drachten location is best known for developing all sorts of consumer products, ranging from toothbrushes and the Senseo, to vacuum cleaners and shavers. We got a great insight in the workings of the company, but unfortunately didn't get the opportunity to visit their Research & Development department, which is of course top secret.

Applied Physics dinner

On February 16 the first edition of the Applied Physics dinner took place in the Nijenborgh. From first year students to professors, everyone from Applied Physics was invited to join and participate. An excellent three course buffet was provided (see photo), with of course plenty of drinks. It was a great informal event to meet and talk to people from our field and get to know the different research groups. It was a great success and we hope it is the start of a tradition.

Internationalisation

As is known by all, our faculty has a significant amount of students from abroad, which is of course the reason our association is transitioning to English. To try to involve foreign students in our student life and thus in study associations, an internationally oriented pub quiz was organised together with the CB and FMF.

ASML lecture

Gerbert Bakker, the chairman of T.F.V. 'Professor Francken' of the year '04-'05, came back to the Nijenborgh after many years of absence. Everyone enjoyed the lunch, took their seats and the attention of the filled room quickly shifted to the speaker. After a quick introduction about his days at Francken he informed us about his career path and his work at the moment. It was an informative lecture about what it takes to be successful at a company like ASML.

Primary school gymnastics

When thinking about primary school gymnastics most people tend to think of dodgeball and 'apenkooien'. Altough dodgeball and 'apenkooi' doesn't seem to be a good combination with Franckenmembers, the Sportcie made it into a great success. The participants were really enthousiastic, maybe even a bit too much from time to time. It was a good two hour workout!

Freshmenparty

It was a long wait for the Freshmencommittee, the first plans were made all the way back in November and on March 10 it was finally there. This year's, quite original, theme (Cowboyboots & Bathingsuits) surprisingly resulted in a lot of people actually wearing theme clothing, although it was quite a cold night. The turnout was great, with a lot of freshmen and older year students and it resulted in a great party!

Life after Francken

A tale of darkest Crouch End

By Bas Vlaming

It's been a while since my most recent contribution to the Francken Vrij came to print. In fact, it might even have been six or seven years ago – which I suppose is already somewhat indicative of my dinosaur-like status by Francken standards. Besides being ancient history, I'm also a bit of a pedant, so let me start my contribution by complaining about being asked to write this edition's "Life after Francken" while still being a full-fledged Francken member. In fact, I might even still have voting rights, although I'd need to refer back to the board members, or to fellow pedants among the *Wijze Heeren*, for confirmation on this. Peyn?

Enough grumbling. I guess a short introduction on yours truly is in place. I started studying physics in 1999 and of course I joined the T.F.V. as soon as I could. However, being

The 2004-2005 Board of T.F.V. 'Professor Francken' in all its glory

wet behind the ears and not quite capable yet of any kind of good judgment, my first few years were mostly spent outside Francken, despite joining the occasional activity (including the buixie to Italy). But even though it took me until my fourth year to

Practising scientists in the good, not-so-old days.

actually join my first committee, I feel I have done my best to atone for that ever since. The pinnacle of my Francken career is, of course, being a member of the 2004-2005 board with Gerbert, Arjan and Sander, more commonly known as Gerbert, Peyn and Onur – a decision I had to mull over at the time, but that I have never regretted.

That was not the end of my time at Francken, far from it in fact. Not long after joining the glorious ranks of the *Wijze Heeren,* I also achieved the slightly less impressive distinction of becoming drs. Vlaming. For you young whippersnappers, a drs. title is what a Master's degree used to be referred to while you were in primary school. Anyway, I decided to stay in Groningen for a Ph.D. in Theoretical Physics. This not only meant four more years in Groningen, working in a great research group (since you ask: Theory of Condensed Matter with Jasper Knoester) on research that I quite enjoyed doing. It also turned out to be four more years of pretty much daily visits to Francken for coffee, many a break spent with *jassen* (I've looked it up but it's untranslatable, really), several buixies, the odd committee here and there, generally having a great time and, as it turns out, meeting some friends for life along the way.

Coffee was consumed in industrial quantities and often dubious qualities

Years passed, papers were published, coffee was consumed in industrial quantities and often dubious qualities, conferences were visited. Since I enjoyed the research life, did a decent enough job of it I suppose and eagerly kept my beady eyes open at the right time for the right opportunity, I decided to stick to science after getting my Ph.D. in 2010. Going for a postdoc is also a brilliant way to go globetrotting, and in June 2010 I moved across the pond to start a

postdoctoral position in the United States, at MIT in Cambridge, MA. As far as new environments go, this was a pretty sweet one. Working and living in a town swarming with Harvard and MIT academics and students, loads of fellow researchers and grad students who are more or less in the same boat, and at a university where you're able to work with some ridiculously smart (and often genuinely nice) people on physics you find truly interesting - it was a great experience that I can heartily recommend to anyone who is on the fence with regards to postdoccing or not. But being across the pond didn't really end my Francken connection, far from it – there were several fellow Franckenians in the northeastern US during roughly that period of time, including some in Boston. Also, various Europe-based conferences and other scientific trips allowed for a Groningen visit several times a year, usually including visits to my old group and also, by implication, to Francken.

But while I quite liked my time at MIT, some unfortunate realities also reared their heads. One such unwelcome reality is the fact that it is rather difficult to make a career out of science, enjoyable as you may find it. It's a highly competitive world with very few full positions for large numbers of interested applicants, and while I did enjoy doing research, I also realised I probably was not good or productive enough, nor willing enough to make the necessary sacrifices to be able to get a full position in the kind of place I would actually want to be at. Still, I went for a second postdoc, but a bit

closer to home: the Max Planck Institute for Physics of Complex Systems in Dresden, Germany. There are many clichés about and prejudices on East Germany, and some of them may be somewhat true, but say what you will, Dresden is truly a great city to live in. Affordable too, which is a quality I can particularly appreciate in retrospect. I will not dwell too much on Germany – I enjoyed the city and the MPI, but professionally it confirmed that the scientist life was not for me.

So, what next? I suppose I had to start working for the Man. But in all honesty, I was never quite blown away by the kind of jobs I heard about while studying physics, also because practicality, machines and fixing stuff are not really my forte. Serendipity had it that at some point I heard about data science training programs in New York and London. I had no clue whatsoever at the time that data science was a thing, let alone what it was, but it looked like it was worth a shot. And, lo and behold, I actually got accepted into the London program – and while the training was frankly speaking not all that useful, it did convince me that this kind of job might be a pretty good fit for me. After a few weeks of vacation, I gathered enough motivation to properly start applying for jobs in October '14. I generally aimed for various quantitative, analytical jobs in both the UK and the Netherlands, with varying degrees of success. I went to the UK for interviews in November, and the choice was fairly easy after that: there was one job offer that was both better and more interesting than the others.

So, since January last year I've been in London, working as a data scientist at Ocado Technology. Ocado is a reasonably sized, steadily growing online grocer here in the UK. It runs both the online business as well as the necessary logistical infrastructure behind it: several large warehouses, an armada of trucks and delivery vans, and all that. As much of the relevant technology as possible is developed in-house, and as it's a young company focusing very much on maintaining a technological competitive edge over the competition, it's a pretty progressive place to work in. So what does a data scientist actually do? Essentially, we do all kinds of analysis and modelling within the company, often in one of two directions: understanding customer behaviour (e.g. producing recommendations, vouchering, webanalytics), and logistics. This usually involves statistics, some programming, handling good amounts of data, potentially some machine learning, but the precise mix really differs quite a lot from project to project. In a number of ways, it's really not all that

You have to suffer through some nerd waffling about his pet programming project, but I can live with that

Dresden

More delightful nostalgia

different from life in theoretical physics: I'm still sitting behind a computer, using all kinds of numerical and mathematical tools to puzzle on some quantitative problem, and drink some coffee while I'm at it – the actual problem might be quite different, but the kind of work is most definitely in the same ballpark. My colleagues tend to have a similar background, many Ph.D.'s and pretty much everyone is a mathematician, physicist or computer scientist. The latter means that occasionally you have to suffer through some nerd waffling about his pet programming project, but I can live with that.

I may have implied earlier that I work in London, but that's not quite true – the job is actually in Hertfordshire, in the rather forgettable town of Hatfield. After my early encounters with the town, I felt at that time, and fortunately also as of yet, that I did not feel sufficiently dead inside to actually live there. Luckily, there are other options. As a wise man once described it, London is the great cesspool into which all the loungers and idlers of the Empire are irresistibly drained; so, I felt I had little choice but to go with the flow, move down to London and take the daily commute on the chin. At least it gives me some time to ponder the meaning of life for about two times 50-ish minutes a day.

Sure, London has its downsides – with living expenses being what they are here, I've regressed from a two-room apartment

right in the centre of Dresden to what's essentially a student room in a shared house in a nice but distinctly non-central North London area. Also, the sheer size of London makes meeting up a lot more inconvenient than in more compact places like Groningen, Dresden or Cambridge. Still, there are a lot of pluses too, and it helps that I've always suffered from a spot of Anglophilia. As another wise man once said: when a man is tired of London, he is tired of life. London is full of gigs including lots of weird dissonant noisy bands or whatever your niche genre of choice is, high-functioning alcoholism is a way of life here, there's a bit of an obsession with football and rugby (although watching it live is stupidly expensive), and with good (though, again, expensive) public transport and six airports in the area, getting anywhere is a breeze. Including weekend trips to the Netherlands, which are quite doable whenever the need or want arises. So, don't be too surprised if I knock on your front door in the near future.

Le'ah!

Bas and his gang

ASML

Nowadays, you can find 16 GB USB sticks on supermarket shelves for as little as €10. This probably isn't something you think about much, but it actually represents quite a significant milestone.

By Jojanneke Meewis-Strijbos

Let's revisit the world of *Moore's Law* for just one moment. It's a highly complex world in which companies everywhere are doubling the capacity of their chips on an annual basis, but not without a high degree of effort. It's a world in which major breakthroughs measure only a few nanometres in size. It's a world in which one of the leading players is located in the Netherlands, or to be more precise, Veldhoven.

Crucial Step

Welcome to ASML, a manufacturer of lithography systems for producing computer chips. ASML supplies equipment to all the world's major chip manufacturers including Samsung, Intel and TSMC.

There are dozens of steps along the path to producing a chip. ASML helps manufacturers take just one of these steps, but it's a very crucial step. Lithography involves exposing and chemically etching the wafers used to 'print' a chip's components. The degree of miniaturization achievable is fully dependent on the accuracy of the lithography process.

With ASML's latest generation of machines, it's possible to print lines on chips measuring only about 20 nm in thickness. To put this into perspective... that's like printing the contents of a 500-page novel onto a centimetre-long strand of human hair!

High-Tech Hotbed

You probably think ASML's machines are incredibly complex. You'd be right. Every day, thousands of engineers and researchers dedicate themselves to refining its machines still further.

Moore's Law is relentless. Driven by cut-throat competition in the high-tech marketplace, the maxim is *smaller, faster, cheaper*. This perpetual race against the clock makes ASML a highly demanding, yet fascinating place to work. It's a high-tech hotbed where state-of-the-art dynamics, precision mechanics, optics, electronics and information technology converge – fully focused on supplying systems that are faster, more accurate and more reliable than their predecessors.

Driving Force

The driving force behind ASML's technological breakthroughs is its forward-thinking engineers. ASML's employees are some of the most creative thinkers in the world of physics, mathematics, chemistry, mechatronics, optics and informatics. And because ASML invests over €800 million annually into research & development, these experts have all the resources at their disposal to push the envelope to an extreme. It's the only way ASML can maintain its edge – worldwide.

Learning Environment

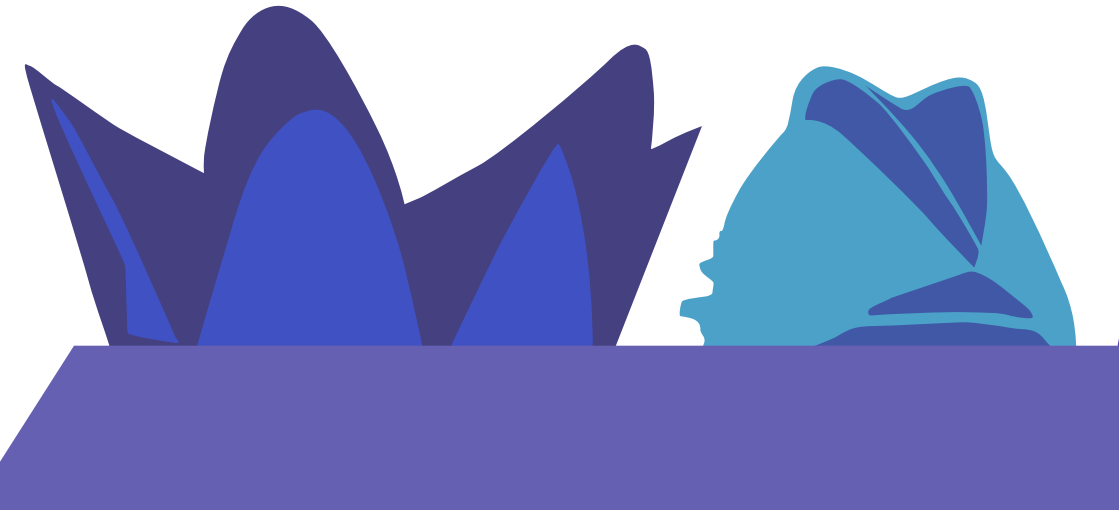
ASML is an ideal environment for professional growth and development. Do you have an unbridled passion for technology? Do you dream of playing on a team that experiments with new ideas every day, that pushes the edge of the envelope and that's driven by the goal of *smaller, faster, cheaper!* If so, look no further… visit our website at www.asml.com/careers.

Francken members abroad

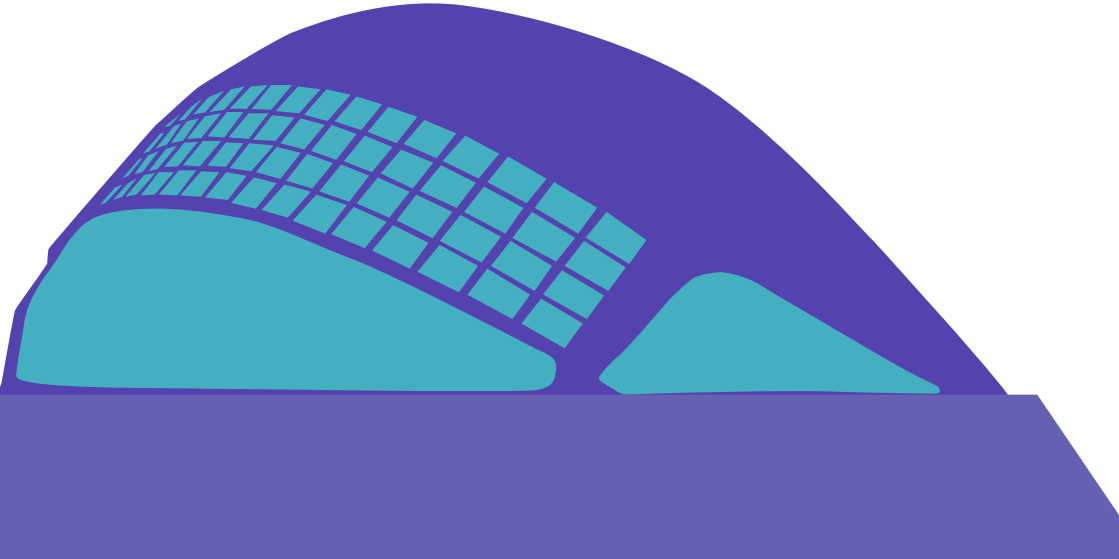
A semester in Valencia

By Nikki Arendse

Ever since I was young I wanted to learn Spanish and study a year in Spain. This year I finally made that dream a reality. The first semester of 2015-2016 I studied Physics at the Universitat de València and it definitely did not disappoint. Spain is an amazing country to live in, with its many sunny days, even in the winter, and lack of rain. Celebrating Christmas was quite an experience as well. They obviously tried their hardest to get into the Christmas spirit, but Christmas lights in orange trees and ice skating in 20 degrees did feel a bit odd.



The first thing I noticed about the people is their warm and welcoming mentality. As an astronomer, I am used to the people around me possessing at least a few autistic characteristics and being somewhat distant towards other people. In Spain it's the complete opposite. Spanish people are extremely curious towards foreigners, and even though their English vocabulary is terribly limited, they try to get to know you right away. In the first week our classmates invited all of the exchange students to their faculty dinner, which was quite the experience. Another characteristic of Spanish people, one probably well known to all of you, is their "laid-back" mentality. If you have an appointment it's perfectly fine to show up an hour late, if you decide to show up at all. This faculty dinner started at 21:30, which is Standard Spanish Dinner Time. Around 22:30 most people had assembled outside the restaurant and they could finally open their doors for us. The total number of people attending the dinner was quite high; around 200. We could not all fit in the restaurant so another room had to be booked which cost everyone another 3 euros. The Spaniards were all outraged by this unexpected price raise. Personally I was more surprised by the fact that they thought it would be a good idea to call out the names one by one, so people could reluctantly pay their extra three euros. This wasn't even done in alphabetical or any other logical order whatsoever, so the chances of you actually hearing your name were astronomically small. Approximately one hour later, most people were finally seated inside. Around midnight the first starters were served, although at this point I wasn't really hungry anymore. The night ended with trying to drag the drunk and very slow walking Spanish people to a club where we were promised a free entrance, which turned out to be not valid for guys (~90% of our company). This is just one of the things you have to get used to when studying in Spain. Another one is food and alcohol being incredibly cheap. One time I walked out of the supermarket with 3 days' worth of food, some make-up, 3 bottles of perfume



A typical view in Valencia

and one bottle of port, for only 30 euros. Unfortunately, this principle did not apply to drinks in clubs. A new challenge arose: planning your alcohol consumption during pre-drinks extremely carefully, balancing the fine line between being sober in the club and having to spend all your money on overpriced cocktails, and not making it into the club at all.

Now is probably the time to talk about the university, to hold off the impression that all I have been doing these past five months is partying. Like almost any science faculty in the world, the physics department of the Universitat de València is located outside the city centre. Unfortunately Valencia is somewhat larger than Groningen, so for me this meant either sitting in a slow tram for an hour, or going by bike for 40 minutes. It goes without saying that I went with the last option, as any Dutch person would do. When I first walked onto the faculty campus and saw a few shabby old buildings next to each other I felt right at home. In addition to palm trees with dates in them (when I discovered this I got extremely excited), there were cats all over the campus. The university turned out to be a shelter place for stray cats. In other words, basically a paradise.

The courses were all in Spanish. I knew this in advance, but still wasn't sure if my minor Spanish at the University of Groningen had prepared me enough for this. It soon turned out it hadn't. Most lectures consisted of a professor reading the exact content of the highly detailed slides in rapid Spanish. It didn't take long for me to conclude that I would be better of just reading them by myself at home, and the lectures weren't really worth attending. There was one ex-

ception, however, where the professor was extremely helpful to us Erasmus students. He changed the original language of the course, Valenciano, to Castellano (normal Spanish) for us, offered us extra explanations in English after the classes, and even answered some questions I sent him by email with extensive LaTeX documents. The pinnacle of his kindness had to be during the exam, when he gave us unlimited time, answered all of our questions and even told me where I went wrong in my calculation.

The time we had for exams strongly depended on the subject. One exam only lasted 2.5 hours, but we also had one of 5 hours, consisting of 2 parts with a short break in between.

Something I hadn't experienced anymore since 'Physics Laboratory I', were lab sessions. Since in Spain they don't have a distinction between astronomy, theoretical physics and applied physics bachelors I couldn't get around it here. I must say the experience I've had in Valencia really confirmed my choice for astronomy: the labs were horrid. We were working for 4 hours straight, from 15:30 until 19:30 (which would include normal Dutch dinner time, but in Spain, of course, they only start eating as late as 22:00). Our tasks mostly consisted of editing tables and graphs in Excel and conducting secondary-school like exercises with solar panels.

Writing the report was kind of rewarding however, since the supervisors would be really impressed when you added standard things such as an abstract and acknowledge-

Max, Nikki and Jasper

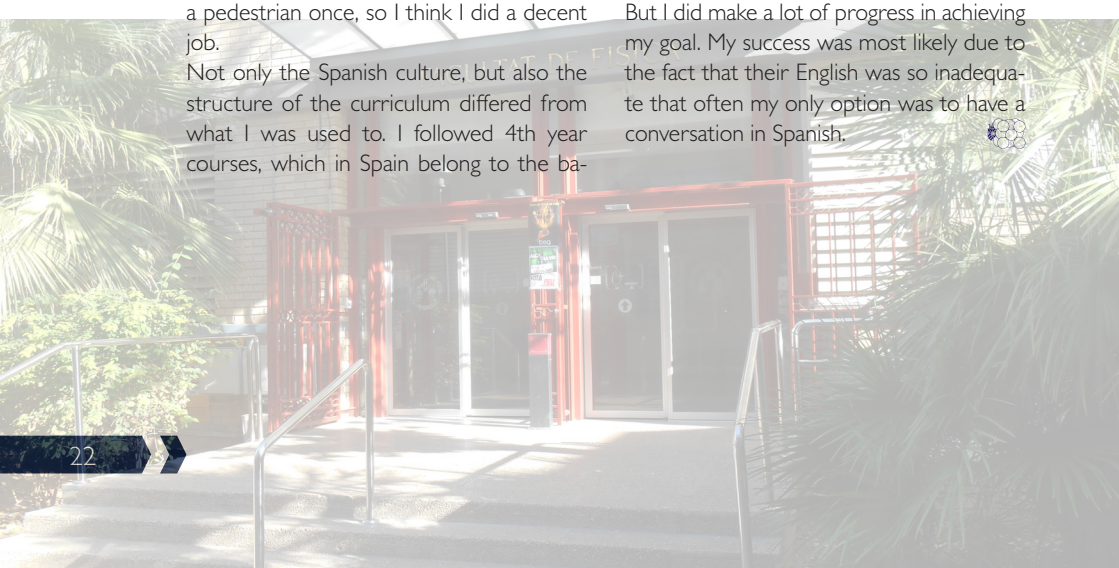
Ciutat de les Arts i les Ciències

ments to your report. I'm proud to say I got my first 9.8 for a report at a university ever. Then, I would also like to add a few words on bicycles in Valencia. If you ever go there, it is extremely important to not leave your bike unattended at night. I made that mistake the first night and never saw my bike again. For the rest of the semester I crammed my bike into the elevator every single day and put it on our balcony.

There are bicycle lanes in Valencia – in theory – but since they have only been around for a few years, nobody is accustomed to them. People do not pay attention when they cross the roads, or put in any effort to avoid walking slowly in the middle of them. When you ring your bell, they take an uninterested look over their shoulders and walk into the direction that is least convenient. My favourite thing to do was cycle past them very closely and very fast, and enjoy their bewilderment as they never saw you coming. I like to believe I contributed to a city in which people treat bicycle lanes with fear and respect, like we do in the Netherlands. In the process I only hit a pedestrian once, so I think I did a decent job.

Not only the Spanish culture, but also the structure of the curriculum differed from what I was used to. I followed 4th year courses, which in Spain belong to the bachelor. After 4 years they have a master program consisting of only 1 year. Another difference is that they divide the year into semesters, so there are only 2 exam periods in a year and the courses take 5 months. I followed three courses at the university; Relativity and Cosmology, Nuclear Physics and Atmosphere, Radiation and Energy, next to a language course to improve my Spanish level as much as possible.

Altogether I really enjoyed my time in Valencia and would recommend studying there to everyone. The level of education is quite high compared to the rest of Spain, so don't let my stories about the labs scare you too much. The subjects were really interesting and it wasn't such a big problem that everything was in Spanish. The advantage is of course that physics is a universal language, which makes it a lot easier to follow than other studies would be. When I didn't understand something it was always easy to find an English explanation online as well. I must say I still find it really difficult to have conversations in Spanish, especially conjugating the verbs can take me a while. But I did make a lot of progress in achieving my goal. My success was most likely due to the fact that their English was so inadequate that often my only option was to have a conversation in Spanish.



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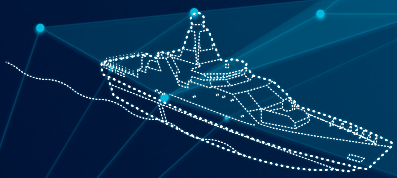


ACTIVE IN DEFENCE, TRANSPORTATION SYSTEMS AND CYBER SECURITY

THALES

Together • Safer • Everywhere

The Green Future

By Xu Yang

"Today the world is united in the fight against climate change. Today the world gets a lifeline, a last chance to hand over to future generations a world that is more stable, a healthier planet, fairer societies and more prosperous economies," said Jean-Claude Juncker, the president of the European Commission, on 12 December 2015 in the UN Climate Change Conference in Paris. The two-week conference witnessed the adoption of the historic Paris Agreement, the first-ever universal, legally-binding global deal involving 195 nations in fighting climate change. Humanity has declared war against climate change, the enemy created by humanity itself."

-12 Dec 2015, World leaders cheer for the adoption of the Paris Agreement

Living in the Netherlands makes it difficult to feel the necessity of fighting climate change. But you might have a different vision if you have ever visited a place where the secondary sector supports the economy. I grew up in such a place, Lanzhou, a city located in a river valley in north-western China. It was one of the earliest industrial centers of China and one of the 30 most polluted cities in the world. I have experienced sandstorms which look exactly like those in the movie Interstellar. I have had mornings when breathing the polluted air can make me throw up. I have told myself too many times that it has to stop, but there was nothing I could do to stop it. Manufacturing brings money and money is the key word of the local government. For them, taking care of the global warming is far less interesting.

Leaving alone the pollutions, even the cleanest manufacturing can cause a huge amount of greenhouse gas emissions. These emissions originate from energy consumption. Today (2010 data) 80.6% of the world's consumed energy comes from burning fossil fuels. To compare, only less than 0.4% is generated from renewable resources such as sunlight, wind, tides, and geothermal heat [2]. An ironic fact is, the amount of energy given by the renewable resources are enormous. For example, the sun delivers about 120,000 TJ solar energy onto Earth's surface per second, this is over 7000 times more than the total amount consumed by human activities [3]. Unfortunately, today the price for solar energy is still around 70% higher than fossil fuel energies [4]. For most governments and companies, this is way too expensive to collect such a natural gift.

Increasing the efficiency of solar cells can help reduce the price of solar energy. The typical efficiency for commercially available crystalline silicon solar cells is around 14% to 19% [5]. In labs scientists have achieved over 46% efficiency using four-junction solar cells [6]. However the exotic materials and complex structures used in these junctions make it even less economical: you may have to pay a hundred times more for the three-time increase in efficiency.

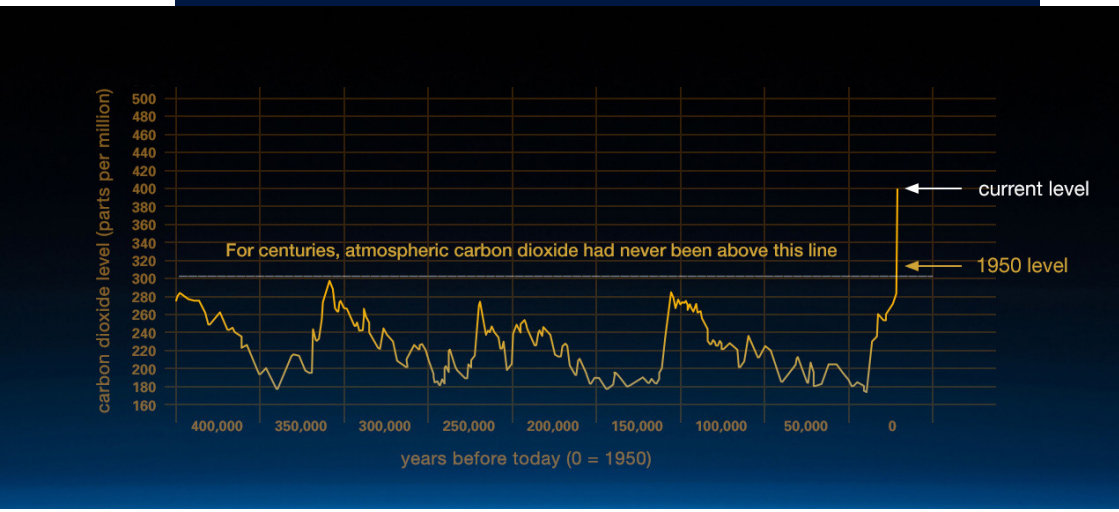
Scientists have also taken another approach, looking for cheaper materials. This idea drives the field of organic photovoltaics. The University of Groningen has played a key role in the development of organic photovoltaics. Now the efficiency of organic solar cells can reach up to 11.7% [7]. But the stability of these solar cells remains a problem.

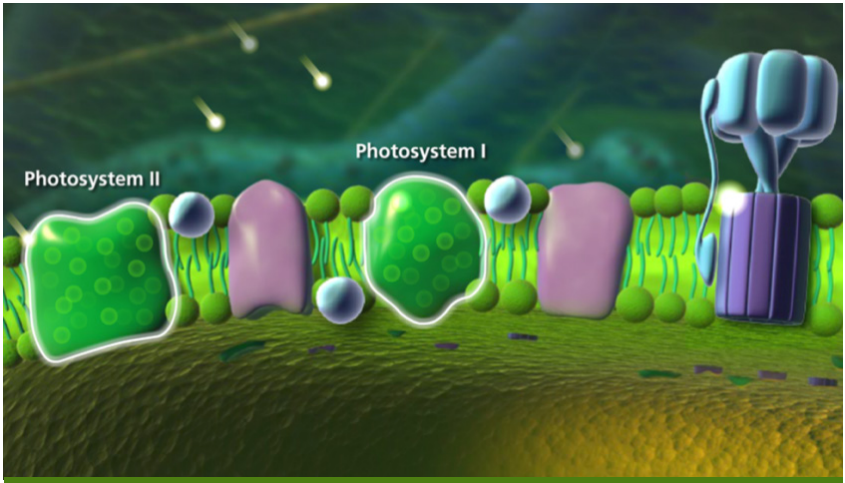
People are also looking for inspiration from nature. Photosynthesis, the only significant solar energy storage process on earth, the food supplier for all forms of life and the origin of most fossil fuel energies, can convert approximately 11% of absorbed solar energy into chemical energy. It is a process that has undergone over 3 billions of years of evolution and optimization. Understanding photosynthesis may lead to something

revolutionary. Photosystem I and photosystem II are the protein complexes where photosynthesis begins[figure 3]. They reside on thylakoid membranes in photosynthetic bacteria or plant chloroplasts. In these protein complexes electrons are excited by photons and then transferred to other locations for water splitting or Kelvin cycle uses. Photosystem I (PSI) even has an internal quantum efficiency close to 100%. This means almost every single photon absorbed by PSI will result in an electron being transferred away. That makes PSI especially interesting for scientists.

Here the Zernike Institute for Advanced Materials undergoes a collaboration on PSI involving 7 research groups. We investigate the theory, structure, properties, and applications of this protein complex. In the group Physics of Nanodevices we focus on using graphene electrodes to study the electrical and magnetic properties of PSI. Graphene is a famous Nobel-prize winning

There are various data stressing the significance of taking this action. According to NASA, the atmospheric CO_2 level has been skyrocketing since the beginning of 20th century. It has surpassed its 650,000-year high in 1950 and has ever since been increasing with an astonishing speed. It is now setting a historical record every year. In the past century, the global sea level has risen 17 centimeters, and the acidity of surface ocean waters has increased 30%. The 10 warmest years in history all happened since 2000, and the September Arctic sea ice coverage is declining at a rate of 13.4% per decade [1]. Shocked? Don't forget, situations like this may escalate at exponential rates.





Photosystem I and photosystem II, together with other photosynthetic proteins on the thylakoid membrane.

2D material. It is a single layer of carbon atoms arranged in a honey-comb shape. It has very high electron conductivity and long spin lifetime. Furthermore, it is transparent for visible light. It is almost an ideal tool for studying PSI. But the problem is, how to connect PSI to graphene?

We have developed a technique of using a peptide as a binder between PSI and graphene. A peptide is a short chain of amino acids. It can fold into a special shape in 3D space and bind to other molecules or surfaces via supramolecular interactions. Using a method called phage-display, one can select one peptide out of all 10^9 different possibilities, to bind to a specific molecule or surface. With the help of this technique we found a peptide that can bind PSI to graphene surface, and it worked surprisingly well. With this peptide, the PSI can self-assemble to graphene surface to form a densely-packed, uniform monolayer. And the electrical coupling between PSI and graphene is much stronger than other self-assembled molecular junctions. Furthermore, nearly 100% of the PSIs are oriented correctly for the photo-excited electrons to be transferred in one direction—toward graphene surface.

Now we are able to study how this self-assembled PSI monolayer influences the electrical properties of graphene. This is

important to know in order to understand the electron transfer of PSI. We build field-effect transistors with graphene. Normally, with increasing back-gate voltage, the resistance of the graphene channel will first increase, reach a maximum, and then decrease. The point where the channel has maximum resistance is called a charge neutrality point. We have observed a large shift of the graphene charge neutrality point after immobilizing PSI on it. We are now still trying to understand this phenomenon, and therefore understand the electron transfer mechanisms within PSI.

One of the most surprising discoveries about the electron transfer of PSI is that the electrons coming from PSI have their spins pointing in the same direction. This was never expected by physicists or biologists, because the energy difference between different electron spin states is too small for nature to use. We know that nature is a master of classical mechanics, it always tries to lower potential energies. Now apparently, nature also knows how to use spin, a purely quantum mechanical concept, to do something that we don't understand. We will also try to understand this phenomenon with the help of graphene.

Armed with a better understanding, we can find new and improved applications for PSI. We hope it can give us a cheap source of energy, cheaper than fossil fuels. There already exist solar cells with PSI active layers. But the efficiency is way too low to be practical. Now with the help of this peptide, we can control the orientation of PSI. An oriented PSI active layer will hopefully bring higher efficiency. At the same time, using graphene as electrodes allows us to stack multiple active layers together and achieve higher efficiency per unit area. Apart from generating electricity, PSI can also help produce clean fuels. It can be integrated with platinum nanoparticles to split water into hydrogen and oxygen.

Nature has given us sunlight, which delivers enough energy to power the entirety of human activities. Nature has also given us PSI, which has been harvesting solar energy for billions of years. Now we start to copy the steps of nature, we start to build our own machineries that can use this little green protein complex to collect sunlight for our needs. We have started our journey towards a sustainable, green future.

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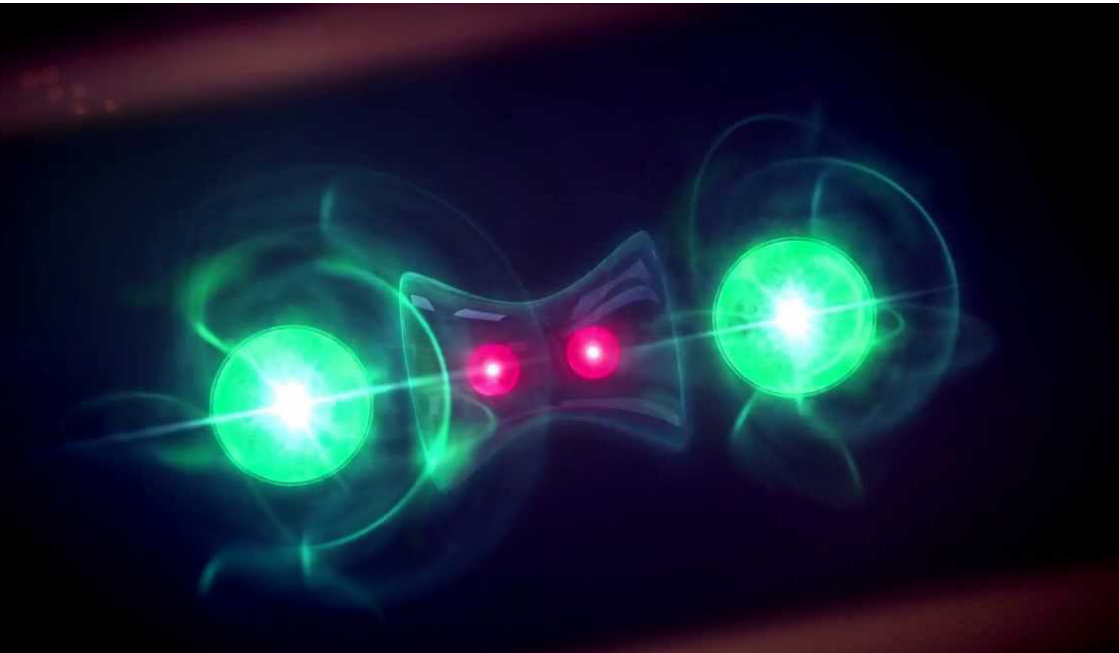
Fig 1. COP Paris Flickr
Fig 2. Vostok ice core data-J.R. Petit et al. NoAA Mauna Loa CO2 record_and nasa.gov
Fig 3. mhhe.com

Puzzle

Entanglement

By Steven Groen

An important phenomenon in quantum mechanics is entanglement. In the theme of Schrödinger's cat, the state 'living cat' is entangled with 'Happy scientist', while the state 'dead cat' is entagled with the state 'Sad scientist'. This is also the theme of this crossword puzzle. Most of the descriptions below are entangled with one, two or three other descriptions. One of the sets of entangled solutions is correct (i.e. it leads to a consistent solution of the entire puzzle), while the other isn't. Try to rule out certain sets of entangled descriptions and fill in the crossword puzzle! Communicate your solution to the redaction and if you have the largest number of correct words, you'll win a bycicle!



Horizontal

H1: If H12 is a measure of current, this is a Griffin. If H12 is a ballroom dance, this is a presidential candidate.

H4: If H19 is a Dutch provincial capital, this is an English preposition. If H19 is a particle, this is a Latin preposition.

H7: If V3 is the set of points equally close to a given point as to a given line, this is an African capital. If V3 is a scientist with a cat, this is a European country.

H8: If H16 is an unlucky South Park character, this is a grandparent of Amalia. If H16 is a noble gas, this is a measuring technique.

H10: If V11 is a European capital, this is a mathematical guess. If V11 is an important person in the war of Troy, this is an invariant Hendrik.

H12: If V8 is a Friends character, this is a mearure of current. If V8 is a mystical Roman river, this is a ballroom dance.

H13: If H18 is a sexually transmittable disease, this is Ginger Rogers' dance partner. If H18 is a string of mathematical symbols, this is a South-American country.

H16: If V6 is a sports event, this is a noble gas. If V6 is a French region, this is an unlucky South Park character.

H17: If V2 is a planet, this is a South Park addict. If V2 is a redactional member of Francken Vrij, this is a French/Swiss cheese.

H18: If V13 is a muppet, this is a string of mathematical symbols. If V13 is a popular ray-finned fish, this is a sexually transmittable disease.

H19: If V18 is a Roman god, this is a Dutch provincial capital. If V18 is an actor and car, this is particle.

H20: This is a physicist with a cage.

Vertical

V2: If H17 is south park addict, this is a planet. If H17 is a yellow sort of French/Swiss cheese, this is a redactional member of Francken Vrij.

V3: If H7 is an African capital, this is the set of points equally close to a given point as to a given line. If H7 is a European country, this is a scientist with a cat.

V5: If V9 is a chinese zodiac sign, this is a form of H_2O. If V9 is the residence of a fictional wizard, this is a mafia boss.

V6: If V16 is an angle, this is a sports event. If V16 isa recent American democratic president, this is a French region.

V8: If H1 is a Griffin, this is a Friends character. If H1 is a presidential candidate, this is a mystical Roman river.

V9: If H10 is an invariant Hendrik, this is a Chinese zodiac sign. If H10 is a mathematical guess, this is the residence of a fictional wizard.

V11: If V5 is a form of H_2O, this is an important person in the war of Troy. If V5 is a mafia boss, this is a European capital.

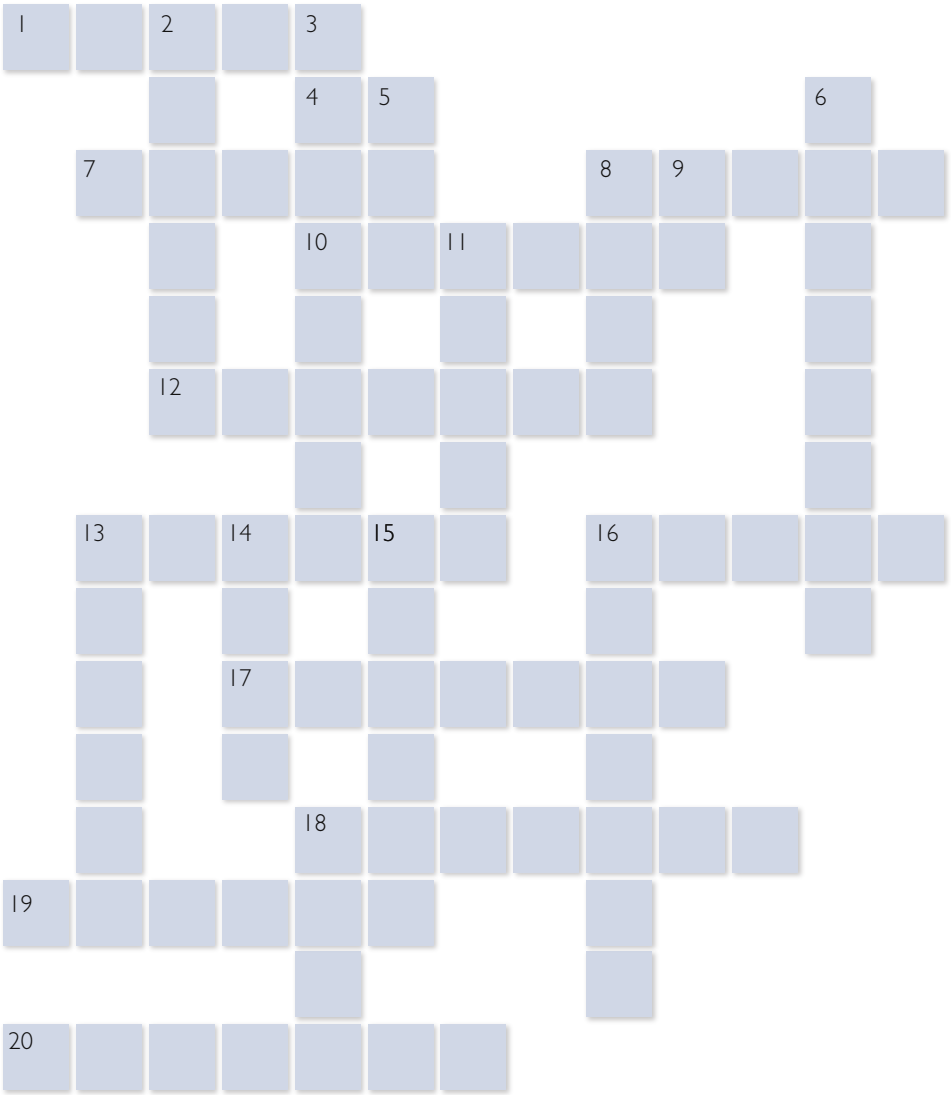
V13: If V14 is an abominable snowman, this is a muppet. If V14 is a Katy Perry hitsingle, this is a popular ray-finned fish.

V14: If H13 is Ginger Rogers' dance partner, this is a Katy Perry hitsingle. If H13 is a South-American country, this is an abominable snowman.

V15: This is a legendary physicist who studied classical mechanics.

V16: If H8 is a measuring technique, this is an angle. If H8 is a grandparent of Amalia, this is a recent American democratic president.

V18: If H4 is an English preposition, this is a Roman god. If H4 is a Latin preposition, this is an actor and car.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Quantum Gravity

By Remko Klein

As is tradition every Francken Vrij comes with a De Theoreet column. Another tradition is that the person who writes it should do so under the stress of a rapidly nearing deadline. As I have somehow turned from a onetime stand-in for Compaijen into the regular writer, here I am again abiding this very tradition. In fact, I am writing this piece well after the deadline I was given. However, I'm sure the editors simply give us false deadlines since all my pieces so far have been written well after the 'deadline', suspiciously without causing any apparent problems…

Now, the attentive reader might have noticed this piece is in English, whereas my two previous contributions were in Dutch. Apparently, the editors already wanted De Theoreet to be in English for a couple of editions now, but somehow I didn't get the memo. So with the regular request to write a piece, they now included a comment which could be eloquently rephrased as "English motherfucker, do you speak it!?". So, there you go.

Anyway, enough jibber jabber; time for some physics. There are all kinds of cool things a Theoreet could say about quantum theories and their weird properties. For example one could discuss stuff like quantum computing, quantum entanglement and quantum teleportation. However, these specific topics also lie in the domain of interest of engineers. So to minimize the probability of overlap with some other piece, I've chosen to add gravity into the mix, as I can hardly imagine engineers would be compelled to do so.

Quantum vs Gravity

Let's start off with some observations. We know of four forces we believe to be fundamental, namely the weak and strong nuclear forces, the electromagnetic force and

the gravitational force. For the first three we have very successful quantum theories describing them and the fundamental particles that interact via them. That is, we have the Standard Model which describes how the matter particles (quarks and leptons, i.e. the stuff we are made of) interact via the exchange of force particles (the photon for the em-force, the W+/- and Z bosons for the weak nuclear force and the gluons for the strong nuclear force).

Our best theory describing gravity on the other hand is General Relativity, which is certainly not a quantum theory. It is a classical (as opposed to quantum, it is of course relativistic) theory that describes how matter curves space and how the curvature of space affects matter.

Given these descriptions for the four forces, namely a geometric one for gravity and a quantum mechanical one for the others, the first thing you would like to do is combine them to construct a theory of all the forces. Of course people tried this long ago and they concluded that General Relativity is not compatible with our quantum theories. One of the reasons is that General Relativity supposes a space-time which is smooth at all length scales, whereas at the smallest scales space-time should not be smooth due to the interaction with quantum mechanical particles. Another puzzle is that in quantum mechanics information cannot be lost (quantum mechanics is unitary), whereas in General Relativity information loss is possible by throwing stuff in a black hole. These (and more) problems make us conclude that General Relativity cannot be the ultimate theory of gravity, and there must be something else at work.

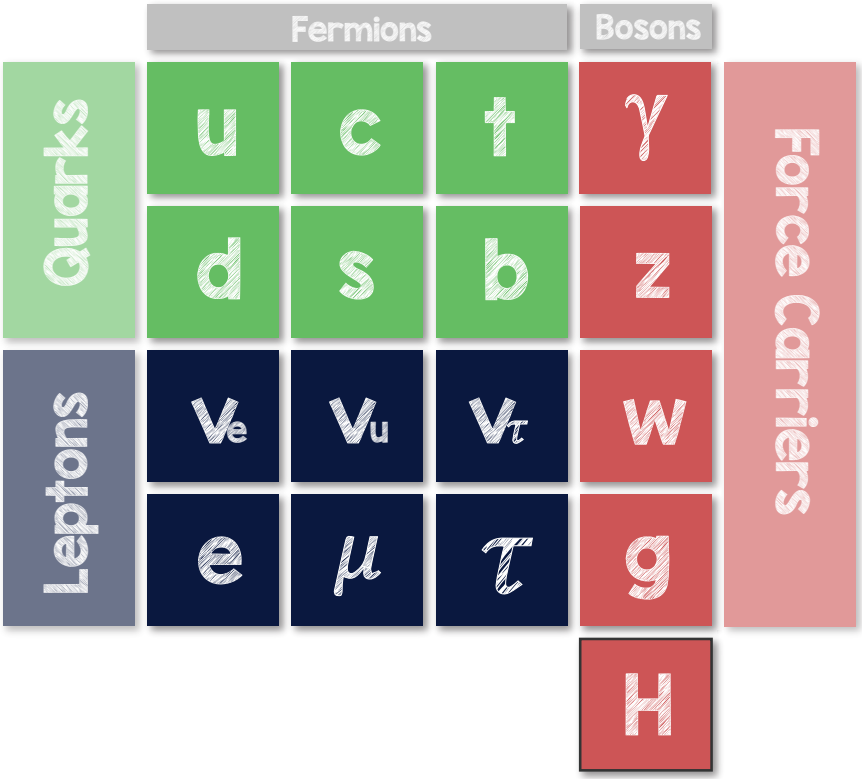
Quantizing Gravity

Given the success of quantum theories in describing elementary particles and their interactions via three of the four forces, a natural next step would be to simply try and construct a quantum theory for gravity. The naïve way to make a theory of quantum gravity is to take General Relativity and quantize it via one of the standard methods that we use to construct quantum theories. In fact, this is precisely what people did in the previous century. Sadly, after going through this procedure you come to the conclusion that your resulting quantum theory is badly behaved: it is haunted by nasty infinities.

Now, infinities are actually integral to almost all quantum theories, but for our successful ones they are relatively superficial: they can be gotten rid of via the process of renormalization. The problem though, is that our quantized General Relativity is not one of those. In this particular case the infinities are rather resilient and you cannot renormalize the theory. This means that the infinities persist, and that in effect you have no idea how to extract meaningful predictions from your quantum gravity theory. As a fundamental theory it just doesn't seem to make sense.

Many valiant attempts have been made to

The standard model



impressive...
but incomplete

quantize gravity in different ways to evade these problems, but so far without real success.

Emergent Gravity and Beyond

Given the difficulty in constructing a sensible quantum gravity theory, one might ask whether we are on the right track. Do we really want to construct a theory of quantum gravity? One of the premises that started such a quest was that gravity is a fundamental force. However, this might not be the case and several research groups investigate precisely this possibility.

One viewpoint, inspired by properties of black holes, is that gravity is thermodynamic in nature. From this perspective it is argued that the gravitational force is something that emerges at 'large' scales (could in principle still be very small though) from a statistical description of an underlying theory of microscopic degrees of freedom. In this sense gravity would be analogous to for example the diffusion force, which is clearly not a fundamental force, but rather something that simply follows from the random motion of molecules. What precisely these microscopic degrees of freedom out of which gravity should emerge ought to be, remains unclear.

Now, if one were to accept such a viewpoint (which is not one shared by the majority of theoretical physicists by the way), one would not have any problem with the difficulty in finding a quantum theory of gravity. In fact, to quantize gravity wouldn't even make sense, much as quantizing the diffusion force would not make sense.

Okay, but why stop at gravity you say? Why not also question the fundamentality of quantum mechanics and the elementary particles? In fact some people (amongst whom 't Hooft is a notable example) do not believe that nature is inherently quantum mechanical. They argue that there should be some deterministic theory underlying our quantum theories of the elementary particles. In that sense the probabilistic nature of our quantum theories would be a 'large' (still very small of course) manifestation of a deterministic theory of degrees of freedom on an even smaller scale.

Now, before we completely derail and run into the philosophical question of the existence of a truly fundamental theory of nature, lets just swiftly finish with the traditional Dutch words: bij deze rust de theoreet zijn koffer.

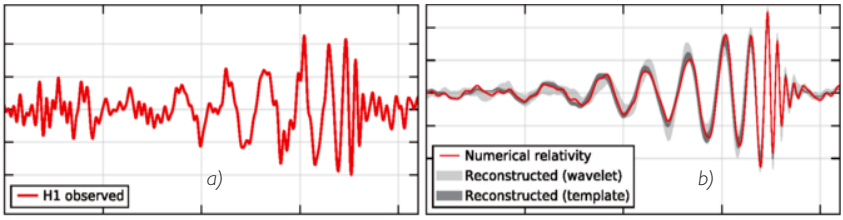


Figure 1: Numerical relativity nicely predicts the gravitational waves signal, but is not compatible with Quantum mechanics (B. P. Abbott et al, 2016)

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