From the Frontiers of Knowledge

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A Career at ASTRON

The Career of Stefan Wijnholds - p. 28 - 30

Periodiek

Recurring Magazine | Issue 2017-2

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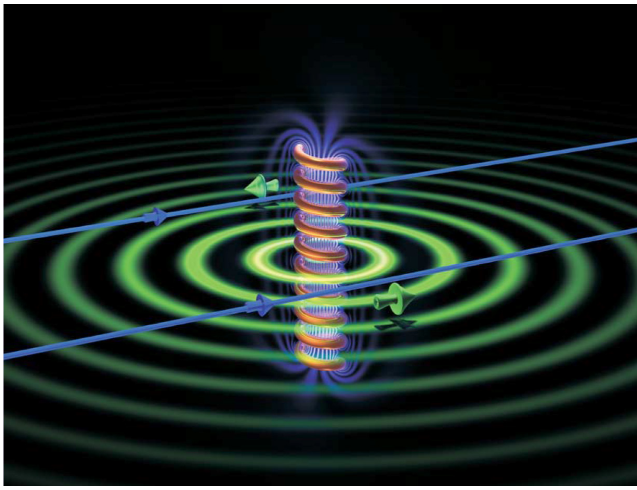
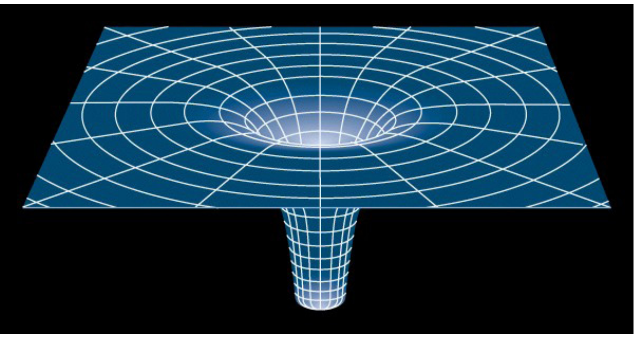
FMF

6 - Wie $\vec{B}$ Zegt Moet Ook $\vec{A}$ Zeggen

The FMF's very own secretary and one of the best teaching assistants of the course Electricity and Magnetism wrote an article on the magnetic vector potential. This unmeasurable quantity is starting to take the place of its curl, the magnetic field. What is it exactly, and what are its applications? Sietse Buijsman explains.



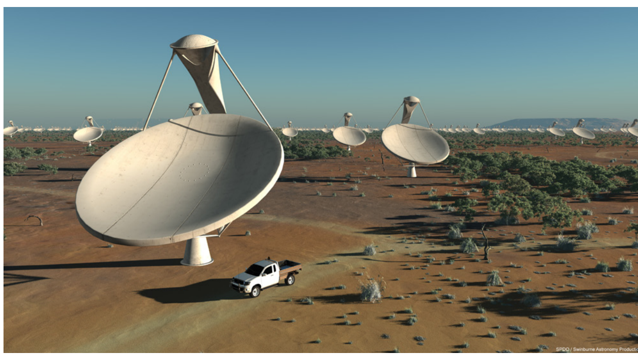


12 - Black Holes versus Quantum Mechanics

Assistant professor Kyriakos Papadodimas from the VSI tells us about black holes and their entropy. In this aricle he explains the problem of information loss in black holes due to Hawking radiation, and how AdS/CFT correspondence could be a solution to this problem.

28 - Building a Research Career at ASTRON

Professor Stefan Wijnholds is an Astronomy Alumnus who now works at ASTRON. He told his story at the FMF's Physics Alumni Day, and he has written an article about his academic career. An internship during his master landed him a job, and now, before reaching the age of 40, he may call himself professor. Read all about it on page 28!



In this Periodiek

From the Editor in Chief

The end of the year is near. When this Periodiek reaches you, you are probably already enjoying your summer holidays. For the board of editors, it was a nice year, and a few of us will probably continue being editors next year.

Some of you might wonder why we dropped the star in the name 'Periodiek'. We felt the star lost its significance over the years, and has no reason to be in the name anymore. Should you wonder where it came from, you can look in the online archive at edition November 2006, page 21.

This edition has some articles reflecting on this year, including one from the FMF's most prominent first-years member, Robert Mol. The institutes also sent in some good articles, ranging from Black Holes to Solar Cells.

We have some recipes for cold drinks, and a pretty hard puzzle made by Johan and Helena Jager, which will hopefully keep you entertained until the next edition of the Periodiek is published.

-Rick Vinke

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In the news

TU Eindhoven

Howflux

First 3D-Printed Ferroconcrete Bridge

Engineers at the Applied University of Eindhoven have designed a concrete bridge that will be made with a 3D printer. The group, guided by Theo Salet, are currently printing the first ferroconcrete 3D printed bridge in the world.

Ferroconcrete is a type of concrete composed of a plaster surrounding a skeleton made of steel. The engineers have designed the 3D printer such that the steel wires are put directly into the plaster. The 3D printed bridge has two major advantages with respect to conventional concrete bridges. First, less concrete is required to make the bridge. Second, the 3D printer can give any shape to the bridge.

The bridge for cyclists will be placed in September.

TU Eindhoven

Screen Coating Inspired by Moth Eyes

Scientist of the University of Central Florida have developed an anti-reflective coating inspired by the eyes of a moth. The coating has an exceptional reflectance of less than 0.23 percent. Meaning the power ratio between the incident light and the reflected light is extremely small. This makes the coating useful for display devices such as smartphones.

The anti-reflectance film has a moth-eye-like structure. In other words, the film has structured dimples on a nano scale. The dimples are created by a template constructed of self-assembled nanospheres. A fluorakyl coat was added on the film to make the film hydrophobic. Not only does the coating increase the readability of a screen, it also protects the screen from fingerprints and dust.
The coating can be used on solar panels too, to increase transferred power from the incoming sunlight. Since the anti-reflective coating can be applied to flexible substrates the application of the coating is broad.

Optica

Tesla to Groningen

Tesla, the frontier manufacturer of the electric car, is broadening its path into Europe and Groningen is campaigning to be a location for a new manufacturing plant. With the slogan, “Hi Tesla. We are Top Dutch” Groningen is ready for innovative companies.

The North of the Netherlands could be an excellent place for Tesla. First of all, the first electric car was made in Groningen. Sibrandus Stratingh (1785-1841), a chemistry and technology scientist at the RUG, was the first to take Faraday’s principles on electromagnetism into engineering to create a little car. Moreover, Groningen is an excellent centre of knowledge on science and engineering with a focus on sustainable energy.

In some way, it would be surprising for Tesla to choose the Netherlands as a production place in Europe. Even though the campaign speaks of the North as being “Top Dutch”. The Netherlands is not in the top game when it comes to using sustainable energy. Only 5.5 percent of the energy is from a re-usable source, making the Netherlands one of the least progressive countries in Europe regarding sustainable energy. However, an interest from Tesla would be a great opportunity for Dutch engineers and scientist and a wake-up call for our government.

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Nitrogen Area Discovered in a Butterfly-Shaped Star Formation Disk

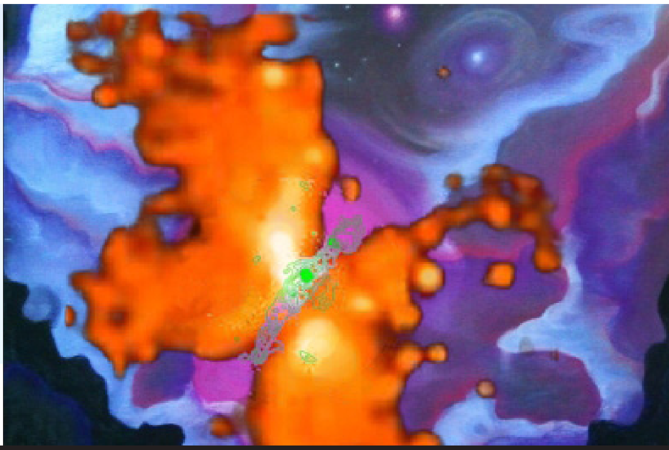
In our very own Milky Way, 7000 lightyears away from Earth, a butterfly-shaped star formation disk is situated. Inside the disk with high-mass young stars researchers found that in the south-eastern part the disk is enriched with nitrogen molecules. Even though oxygen-containing and sulfur-containing hydrocarbons were found throughout the disk. The nitrogen-containing molecules were only strongly present on one side of the disk. The chemical difference in the star-formation region is reason to believe there are protostars present in this region.

Veronica Allen, a PhD student at the RUG and SRON, and colleagues investigated the chemical compounds of hot molecular cores in high-mass star-formation regions. Emissions from the hot cores are directed towards YSO’s (Young Stellar Object), such as protostars. These chemical differences in star-formation regions have been detected earlier on in the Orion.

The research paper is part of a project by an international team of astronomers. The research team uses the ALMA (Atacama Large Millimeter/submillimeter Array) telescope to capture emission lines from molecular gas clouds such as the butterfly-shaped region G35.20-0.74N.

SRON

Groninger Gezinsbode



SRON

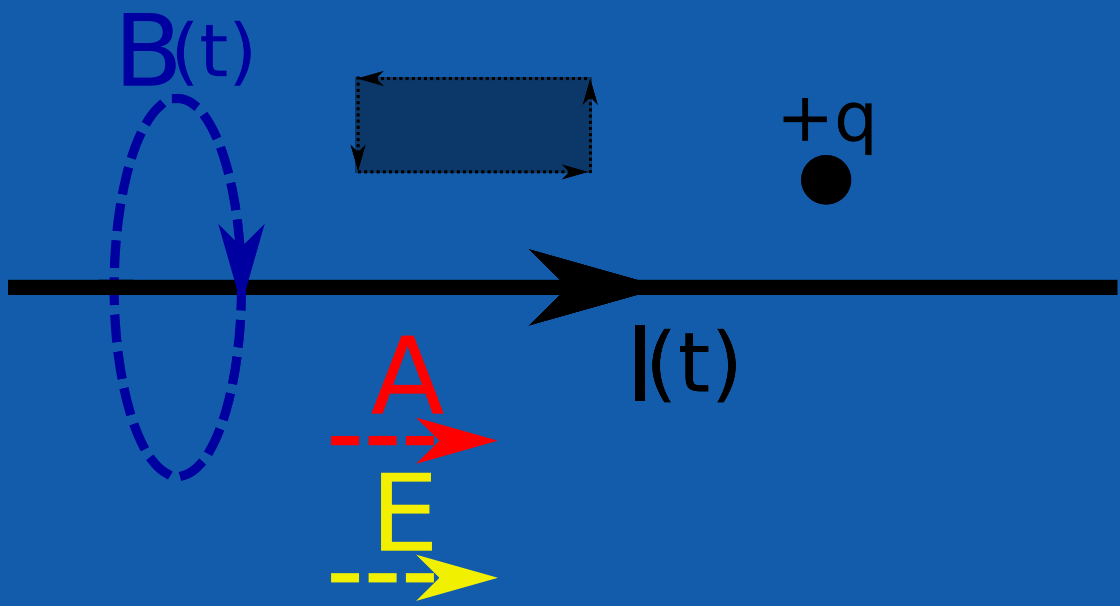


FIGURE 1: A long wire with the fields.

AUTHOR: SIETSE BUIJSMAN

Wie $\vec{B}$ Zegt Moet Ook $\vec{A}$ Zeggen[1]

Elucidation of the Magnetic Vector Potential

Introduction

I have been teaching tutorials for the course Electricity and Magnetism in the third period, which forced me to revisit the theory regarding the magnetic vector potential, commonly referred to as $\vec{A}$. I remember when I was first struggling with the concept, I quickly came to accept it as it was given in the textbook: 'The thing whose curl is B'.

$$\vec{B} = \nabla \times \vec{A} \quad (1)$$

Returning to the textbooks with a better understandig of the theory I kept wondering if $\vec{A}$ carried some physical significance as well as if I could develop some intuition for it, similar to the electric scalar potential V, to which $\vec{A}$ is analogous. Back in the nineteenth century, it was believed that neither the electric nor the magnetic potential held any physical meaning [1]. Nowadays it is believed they do and, since I think this is not widely understood, I would like to share my findings with the reader of this article.

Concept

A good starting point to begin grasping the meaning of a physical quantity is by examining its units. It is easily shown that the units of $\vec{A}$ are $(mass \times distance)/(second \times charge)$. Looking at the units of the electric potential V ('potential energy per unit charge') tells us that we might call the units of $\vec{A}$ 'potential momentum per unit charge'. But what does this *mean*? One could guess that, just like with V, a particle with charge q gains momentum equal to $q\vec{A}$ were we to expose it to $\vec{A}$. This is however not the case. If we put a moving charge in a magnetic field its trajectory will bend, but not in the direction of $\vec{A}$. If we put a stationary charge in a magnetic field nothing will even happen, as stationary charges are unaffected by a magnetic field! So what *does* $\vec{A}$ mean?

It just so happens that James Clerk Maxwell himself had an excellent description of the physical meaning of $\vec{A}$ [2]:

> *"The vector $\vec{A}$ represents in direction and in magnitude the time integral of the electromotive intensity [i.e. the*

momentum caused by the electromagnetic force,] which a particle placed at the point (x, y, z) would experience if the primary current were suddenly stopped."

-J.C. Maxwell

Now this gets us somewhere. According to Maxwell $\vec{A}$ emerges as the momentum a charged particle gets if the current which caused $\vec{A}$ is switched off! Let us examine an example to see the implications of this.

A wire

I will show one example to give you some feel for what $\vec{A}$ means. Afterwards, I would recommend you to look at some examples yourself! I will show you what happens if a charge is positioned next to a current carrying wire and the current is switched off. First I will calculate the final momentum $\vec{p}$ of the particle just by using electric and magnetic fields. Secondly I will show how to arrive at the same result using $\vec{A}$.

Using $\vec{E}$

Consider a long straight wire, carrying current I_0, in the $\hat{z}$ direction. We place a charged particle next to the wire as shown in figure 1. Using Ampère's law, it can be shown that the magnetic field caused by this setup would be:

$$\vec{B} = \frac{\mu_0 I_0}{2\pi s}\hat{\phi} \qquad (2)$$

Where s is the distance to the wire. Now I am going to switch off the current. For the sake of argument, suppose that this goes like $I(t) = I_0(1 - t/k)$ where k is just some time it takes for the current to fully stop and $0 \leq t \leq k$. The dropping current results in a change in $\vec{B}$, which induces an electric field $\vec{E}$ according to Maxwell's equation:

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \qquad (3)$$

It is $\vec{E}$ which causes a force on the particle. We can rewrite this equation by integrating both sides over the shaded area given in figure 1 and applying Stokes' Theorem:

$$\oint \vec{E} \cdot d\vec{l} = -\int_A \frac{\partial \vec{B}}{\partial t} \cdot d\vec{a} = -\frac{\partial}{\partial t}\int_A \vec{B} \cdot d\vec{a} \quad (4)$$

We can plug in equation 2 on the right hand side and perform the integrations. The integration is done of a rectangular loop around the shaded area in the figure. Finally we differentiate to time. This gives us:

$$\vec{E}(s) = -\frac{\mu_0 I_0}{2\pi k}\ln\left(\frac{s}{R}\right)\hat{z} \qquad (5)$$

Here, R can be chosen as the thickness of the wire, for reasons I will not show here for the sake of brevity. I actually cheated a bit, as I omitted a constant resulting from the integration on the left hand side. For a more complete explanation of this problem, look at example 7.9 from [3]. The momentum the particle gains would be the time integral of the electric force over the time that $\vec{E}$ changes:

$$\begin{aligned}\vec{p} &= \int_0^k \vec{F}\, dt = q\int_0^k \vec{E}\, dt \\ &= q\frac{\mu_0 I_0}{2\pi}\ln\left(\frac{s}{R}\right)\hat{z}\end{aligned} \qquad (6)$$

Thus, as the current is switched off, the particle gains momentum in the $\hat{z}$ direction until $t{=}k$, when $\vec{E}$ vanishes. The particle will then continue moving at constant velocity.

Using $\vec{A}$

Now let's try applying Maxwell's statement. According to Maxwell, the momentum calculated in equation 6 should be equal to $q\vec{A}$. This can be shown using equation 3 if we substitute equation 1:

$$\nabla \times \vec{E} = -\frac{\partial}{\partial t}\nabla \times \vec{A} = -\nabla \times \frac{\partial \vec{A}}{\partial t} \qquad (7)$$

And so:

$$\vec{E} = -\frac{\partial \vec{A}}{\partial t} \qquad (8)$$

This is valid as long as there is no scalar potential, V present. We can substitute $\vec{F} = q\vec{E}$ and integrate both sides to time:

$$\vec{p} = \int_0^k \vec{F}\ dt = q \int_0^k \vec{E}\ dt$$
$$= -q \int_0^k \frac{\partial \vec{A}}{\partial t}\ dt = q\vec{A}(t=0) \qquad (9)$$

The last step is justified by using that $I(t=k) = 0$, so $\vec{B}(t=k) = 0$ and so $\vec{A}(t=k) = 0$. Calculating $\vec{A}$ from equation 2 gives us:

$$\vec{A} = \frac{\mu_0 I_0}{2\pi} \ln\left(\frac{s}{R}\right)\hat{z} \qquad (10)$$

Where again R can be chosen as the radius of the wire. Plugging this back in the result for 9 yields:

$$\vec{p} = q\vec{A}(t=0) = q\frac{\mu_0 I_0}{2\pi} \ln\left(\frac{s}{R}\right)\hat{z} \qquad (11)$$

This is the same as in equation 6, exactly as Maxwell has told us!

Conclusion

As we have seen, $\vec{A}$ can be regarded as 'stored momentum'. As long as the current in the wire remains constant, the charged particle remains stationary. As soon as the current is switched off, the 'stored' momentum is released and the particle will start moving in the direction of $\vec{A}$. Once the current has completely stopped, the total momentum of the particle will be equal to $\vec{A}$.

In [1] it is explained how in electromagnetic interactions the total conserved momentum is not just given by $\vec{p} = m\vec{v}$, but:

$$\vec{p} = m\vec{v} + q\vec{A} \qquad (12)$$

Which can be clearly seen from previous example. Before the current switches off, the particle is stationary, so $\vec{v} = 0$. After the current is switched off, $\vec{A} = 0$ and the particle is free with momentum $\vec{p} = m\vec{v}$.

Some may recollect how in relativistic electrodynamics the electromagnetic potential can be expressed as the four vector $\vec{P} = [\phi, \vec{A}]$, where ϕ is the electric scalar potential. This might remind you of the four momentum of a free particle, $\vec{P} = [E, \vec{p}]$. Now you can see how ϕ, the 'stored energy per unit charge' goes in the energy 'slot' whereas $\vec{A}$, the 'stored momentum per unit charge' goes in the momentum 'slot' of the vector.

Discussion

In the last step in equation 9, of course $\vec{A}(t=k)$ does not have to be zero at all. Because of equation 1, we can add any vector field $\vec{A}_0$ as long as $\nabla \times \vec{A}_0 = 0$ and $\vec{B}$ would be unaffected by it. I implicitly assumed that our $\vec{A}_0$ is independent of time, making it drop out in the last step of equation 9. Anyway, my purpose here was not to give an extremely rigid proof of an equality, but just provide you with some conceptual understanding of what $\vec{A}$ means and how it fits in the context of electromagnetic theory.

From this example, it is not immediately evident that $\vec{A}$ is a physical quantity and not just a mathematical construct. There have been experiments that do show this, however. For example, Aharonov and Bohm hypothesised how $\vec{A}$ on the outside of a solenoid (where $\vec{B}$ is zero) could influence a double-slit experiment [4]. This experiment has later been conducted in various setups and have confirmed the effect of $\vec{A}$ [5,6]

Richard Feynman even claimed at one of his lectures that ϕ and $\vec{A}$ are the only fundamental quantities, whereas $\vec{E}$ and $\vec{B}$ only emerge from these:

"The entire theory of quantum electrodynamics has the

FIGURE 1: Two electrons passing by a long current-carrying solenoid on opposite sides (along the blue trajectories) illustrate the magnetic Aharonov-Bohm effect. Although the solenoid's magnetic field (purple flux lines) is almost entirely restricted to the coil's interior, the vector potential $\vec{A}$ outside (tangential to the green coaxial circles) falls off only as $1/r$ with distance r from the axis. One of the two trajectories is parallel to $\vec{A}$ (at the point of closest approach), while the other is antiparallel. Even in the absence of any Lorentz force on the electrons, that difference produces a quantum mechanical phase shift between their wavefunctions.

vector and scalar potential as the fundamental laws and the equations for those replace the Maxwell equations and the $\vec{E}$ and the $\vec{B}$ slowly disappear as the physics becomes more modern."

- R. Feynman

Als dit het geval is, moeten we inderdaad als we $\vec{B}$ zeggen ook $\vec{A}$ zeggen•[1]

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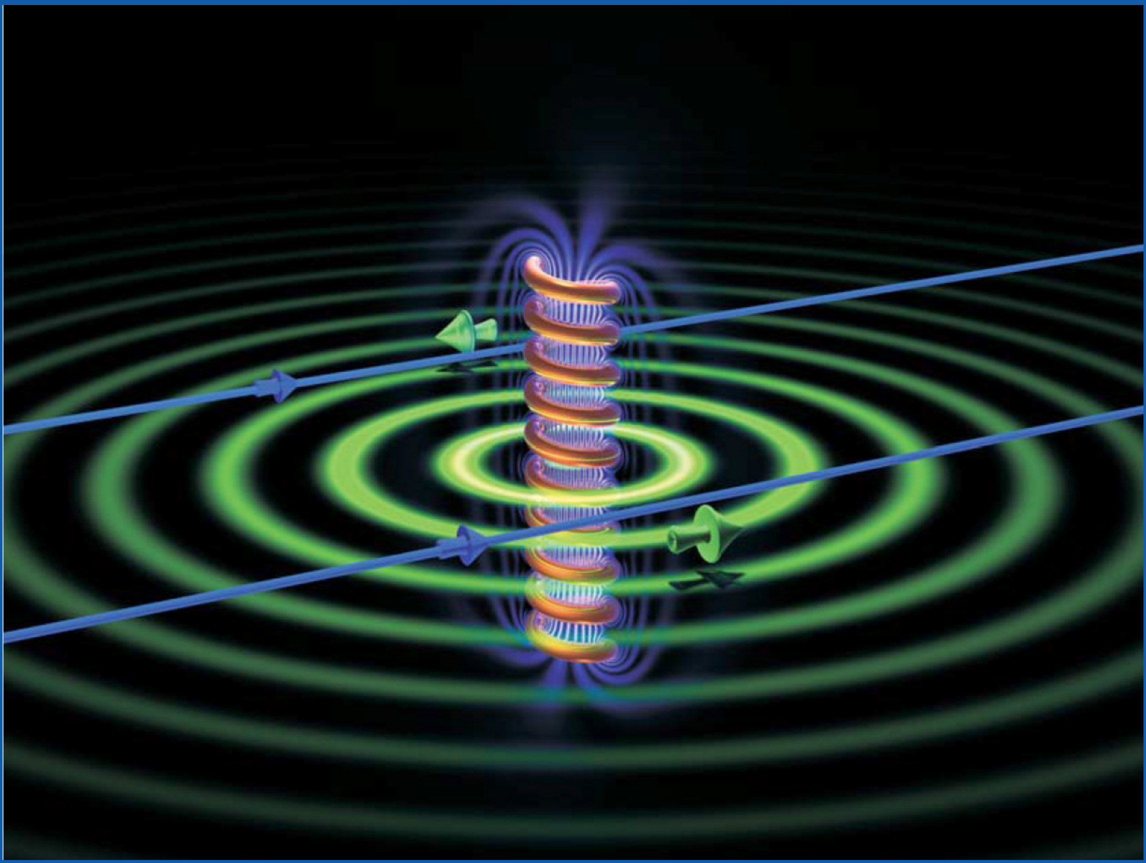
1 The board of editors apologises for the use of Dutch in this article



ASML Internships: an experience in progress that will help shape your career

These days, you can find 16 GB USB sticks on supermarket shelves for as little as €10. In hospitals, a camera the size of a pill can be swallowed to survey a patient's intestines. And in the oceans, tiny GPS transmitters track endangered turtles to help protect them. While each of these devices is incredibly small, it actually represents a big milestone in technological progress.

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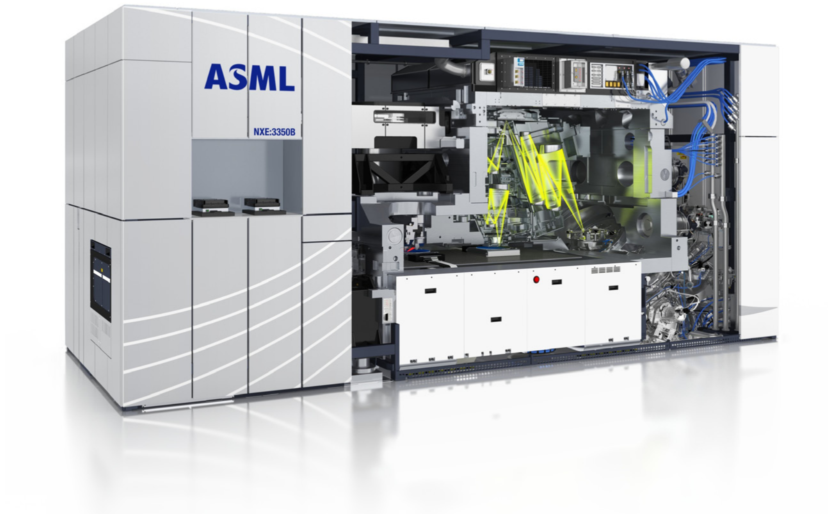

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Black Holes versus Quantum Mechanics

AUTHOR: PROF. DR. KYRIAKOS PAPADODIMAS

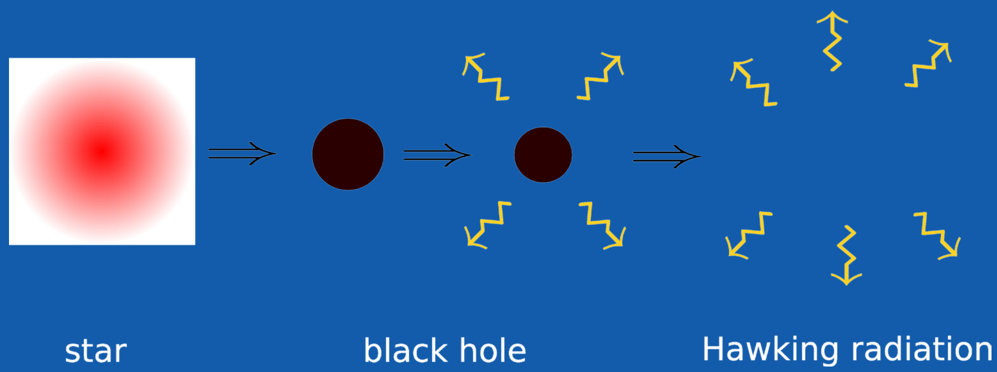

FIGURE 2: The black hole information paradox: a star collapses into a black hole which eventually evaporates via emission of Hawking radiation. The final radiation is "thermal", and paradoxically it appears not to contain the information of the initial state.

Even though fundamental physics has made tremendous progress in the last two centuries, the nature of the universe at the most basic level remains largely unknown. Some of the most profound mysteries are related to the nature of the gravitational force.

According to Einstein's theory of general relativity, gravity is not just another force, but rather it is a manifestation of the curved geometry of spacetime. A massive object, like a star, bends spacetime in its vicinity, and as a result other objects move around it in curved trajectories, like those of the planets.

Black Holes

If the concentration of mass exceeds a certain limit, the curvature of spacetime becomes so large that the star collapses and forms a very mysterious object, a black hole. This is a region of spacetime surrounded by a sphere called the horizon, a 'point of no return'. Everything that crosses the horizon is sucked into the black hole – not even light can escape. More precisely, once you cross the horizon it is impossible to stay at a fixed location in space. Instead you are pulled towards the center of the black hole, where a very strange region exists: the black hole singularity. At the singularity the tidal forces of gravity diverge to infinity, destroying everything that falls in there, and the laws of physics, as we know them today, break down.

Hawking Radiation and Entropy

While general relativity is very successful in describing classical aspects of black holes, once we consider the quantum mechanics of black holes we are faced with significant puzzles. The origin of these puzzles is the discovery of Hawking [1]; due to quantum effects black holes emit some form of radiation. For a solar-mass black hole the temperature of this radiation is about 10^{-8}K, which would be incredibly difficult to measure directly. However, there is compelling theoretical evidence that the calculation of Hawking is essentially correct. As a black hole radiates, it loses energy and becomes smaller. After a long time it completely evaporates, leaving behind just the Hawking radiation flying away in interstellar space.

The discovery that black holes radiate, has led to some of the most important problems in theoretical physics. The first puzzle is that of black hole entropy. According to arguments of Bekenstein and Hawking, the entropy of a black hole is proportional to the area of its horizon and given by the formula

$$S = \frac{k_B c^3}{4\hbar G} A$$

This is puzzling, because usually the entropy of a system is proportional to the volume, rather than the area. Moreover, in statistical mechanics, the entropy of a system is given by the logarithm of the number of microstates N by the formula $S = k_B \log(N)$. From these equations we find that a solar mass black hole has $N=\exp(10^{77})$ possible internal microstates. Notice the double exponential! This is an incredibly large number. The question "what is the meaning of the huge number of quantum black hole microstates" remains an important challenge for any theory aiming to unify quantum mechanics and gravity.

A related important puzzle is the so-called black hole information paradox. According to Hawking's computation, the radiation which is emitted by a black hole is similar to that of 'black body radiation'. This means that the amount of information contained in the Hawking radiation is very small, as it is fully characterized by just one parameter, the temperature. On the other hand a black hole of a given mass can be formed by a very large number of possible initial states, which all have the same mass but differ in other small details. The Hawking calculation seems to suggest that different initial states of the same mass, lead to the same final state or equivalently, that information is destroyed at the fundamental level (since we cannot reconstruct the initial state from the final state uniquely). This is different from the 'information loss' when you erase a file on your computer, or if you burn a piece of paper with some notes on it. In these cases, information is not really destroyed, but rather it gets scrambled in such a way that it becomes incredibly difficult to recover. Instead, Hawking's computation predicts that during black hole evaporation information disappears from the universe completely. This prediction goes against the foundations of quantum mechanics, which requires that information is always preserved and hence we have a paradox. The black hole information paradox has led to a theoretical crisis, which is still not fully resolved. In particular in the last few years this paradox has been significantly refined and reformulated as the firewall paradox [2].

AdS/CFT Correspondence

A promising approach to address these questions is based on the 'holographic correspondence', also known as the AdS/CFT correspondence, which was discovered in 1997 by Maldacena [3]. The AdS/

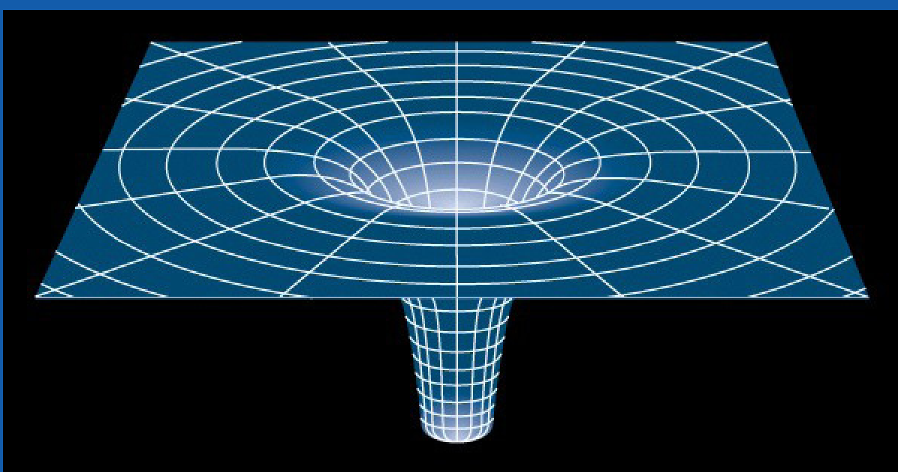

FIGURE 1: The curved spacetime geometry near a black hole.

CFT correspondence allows us to describe all of gravitational physics, including black holes, by using a lower-dimensional quantum field theory without gravity living on the boundary of spacetime. This correspondence follows from string theory and is consistent with the observation that the black hole entropy is given by the area of the horizon, which plays the role of the boundary of the black hole. The AdS/CFT correspondence has proven that information is not fundamentally destroyed during black hole evaporation. This does not mean that the calculation of Hawking is wrong, but rather that the calculation of Hawking is a 'leading-order approximation', and there are additional small corrections which encode how the information escapes. The AdS/CFT correspondence has also provided us with a way to understand the black hole entropy and to identify the meaning of different black hole microstates.

Concluding Remarks

While several aspects of the information paradox have thus been clarified, the questions of what happens inside a black hole and in particular at the singularity, remain open. Some of the theoretical research that is taking place at the Van Swinderen Institute (VSI) at the RUG is focused on addressing this question. Recently a proposal was put forward on how the interior of a black hole can be described using the holographic correspondence [4]. This proposal has highlighted some novel aspects of the black hole information paradox, and it falls in line with recent developments in theoretical physics, which suggest that spacetime and gravity may be emergent notions. What this means is that spacetime may not be fundamental, but rather an effective description. There are indications that the geometry of spacetime emerges from the quantum entanglement of underlying fundamental degrees of freedom, a theme which is going to be explored at VSI in the next few years. The long-term vision is that these theoretical investigations on the unification of gravity and quantum mechanics may lead to a deeper understanding of the nature of space, time, and gravity at the fundamental level, which may be important for a complete understanding of black holes and cosmology•

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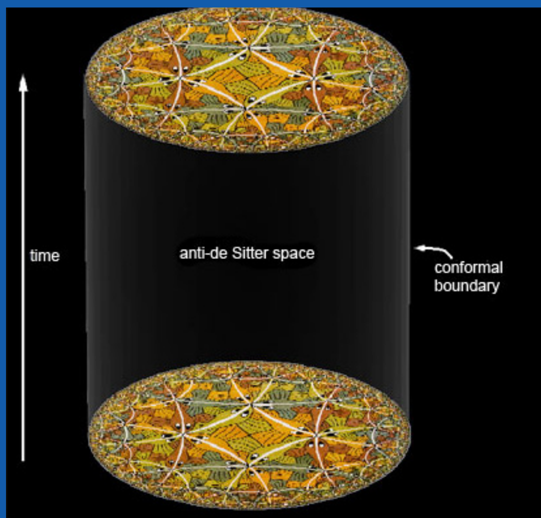

FIGURE 3: The holographic principle (AdS/CFT correspondence) relates quantum gravity in anti-de Sitter space to a lower dimensional quantum field theory without gravity living on the boundary of spacetime.

Towards a New Generation of Super-thin and Highly Efficient Solar Cells

AUTHOR: **BART GROENEVELD**

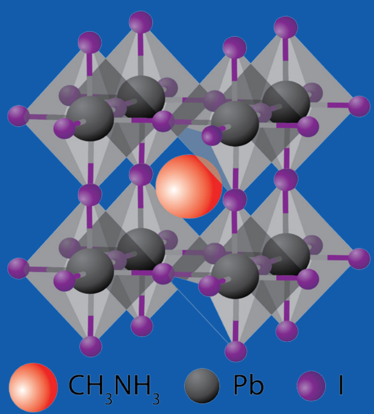

FIGURE 1: Schematic perovskite structure of $CH_3NH_3PbI_3$.

Every year, the global demand for energy increases. The majority of this energy demand is met by burning fossil fuels, which has led to the global warming effect. To prevent even more emission of carbon dioxide it is necessary to use renewable alternatives. A good candidate for large-scale global energy generation is the use of photovoltaics. Traditional solar cells that can be found on rooftops are typically made of silicon, and these solar cells have an efficiency of about 25%. However, these cells are very heavy because they require a lot of material for an efficient device. This is due to the low absorption coefficient of silicon, which means that the silicon layer should be quite thick to absorb a significant amount of sunlight. Their weight limits the use of these silicon solar cells to rooftops. Imagine that one could use a very thin and lightweight, yet highly efficient solar cell on virtually any surface. It would be possible to generate energy from sunlight in much more places than currently. It could potentially be the solution to the global warming problem. The material that could make this reality is called perovskite.

In the past few years, hybrid organic-inorganic perovskite solar cells have seen a tremendous increase in their power conversion efficiency (PCE). The ratio of electrical power output to the incoming solar power, went from 3.8% [1] to a state-of-the-art value of over 22%.[2] A perovskite has the general structural formula ABX3, where A and B are cations and X is an anion. The most used perovskite material in solar cells is methylammonium lead iodide (CH3NH3PbI3, see Figure 1), which is a strongly absorbing semiconductor with good charge transport properties [3]. The high absorption coefficient of the perovskite material means that only a thin layer (on the order of hundreds of nanometers) is needed for an efficient solar cell, as opposed to the standard silicon solar panels that you see on rooftops. This means that the perovskite solar cells could be made lightweight and low-cost, which are two of the major advantages of this material.

A perovskite solar cell consists of several layers. The perovskite layer acts as the absorbing layer (also called active layer) of the solar cell. Upon absorption of a photon this layer creates an electron and a hole, which need to be extracted at the cathode and anode, respectively, in order to create a current through the device. For good device performance it is crucial that the charge carriers do not meet anywhere in the device, since recombination decreases the current and hence the efficiency of the solar cell. This can be ensured by making use of so-called charge transport layers, which can transport one kind of charge carrier and selectively block the other kind due to the positions of their energy levels. Between the active layer and the cathode we have the electron transport layer (ETL) and on the other side of the active layer is the hole transport layer (HTL). By varying these materials it is possible to optimise the performance of a perovskite solar cell.

The majority of the high performance solar cells use a structure where one of the transport layers is processed at a high temperature (around 450°C). This high temperature is undesirable for a number of reasons (such as upscaling of the production), and researchers have come up with alternative materials that do not require these temperatures. An example of a hole transport layer made at lower temperatures is nickel oxide (NiOx). Recently, nickel oxide has been used as HTL in perovskite solar cells with efficiencies ranging from 10 to 17.7% [4][5]. This is mainly because of the high open-circuit voltage, the voltage at which the current is zero, which is around 1.0 V or higher. Often, this HTL is combined with PCBM (phenyl-C61-butyric acid methyl ester) as the electron transport layer. Previous work by our group demonstrated that perovskite solar cells with an ETL made of PTEG-1, a fulleropyrrolidine with a triethylene glycol monoethyl ether side chain, can improve the power conversion efficiency of these cells [6]. Inspired by these results, we tried to optimise the performance of NiOx-based perovskite solar cells by comparing the use of PCBM and PTEG-1 as ETL. The results of this comparison are seen in Figure 2. The device with PCBM has a power conversion efficiency of 11.8%, whereas the PTEG-1 device performs better with a PCE of 13.1%. These findings support the conclusions from our previous paper, which means that PTEG-1 is a better choice for the electron transport layer for various device structures in perovskite solar cells. After our initial experiments we tried to optimise the device structure by varying the thicknesses of both the electron and hole transport layer. Through this optimisation we succeeded in making a perovskite cell with NiOx and PTEG-1 with a 16.1% power conversion efficiency. This is among the highest reported values for nickel oxide-based perovskite solar cells.

Currently, we are working to improve the efficiency of our solar cells even further. One of our strategies is doping the nickel oxide layer to improve its conductivity, which we believe is one of the limiting factors in our device. This can be done by introducing different atoms (e.g., copper) in the nickel oxide structure. In addition, we will also investigate perovskite materials, where the elements at the A, B or X position are different. This has proven to be a good strategy for improving the power conversion efficiency in other studies•

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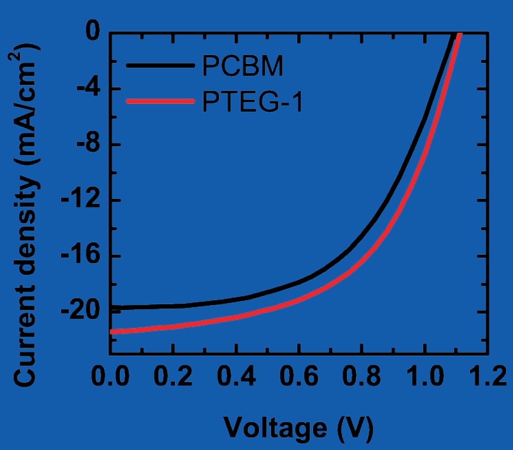


FIGURE 2: Current density-voltage curve for NiO_x-based perovskite solar cells with an ETL made of PCBM or PTEG-1.

PHILIPS

Lightning Research at KVI-CART

AUTHOR: DR. B.M. HARE, PROF. DR. A.M. VAN DEN BERG, PROF. DR. O. SCHOLTEN, T.N.G. TRINH, MSC.

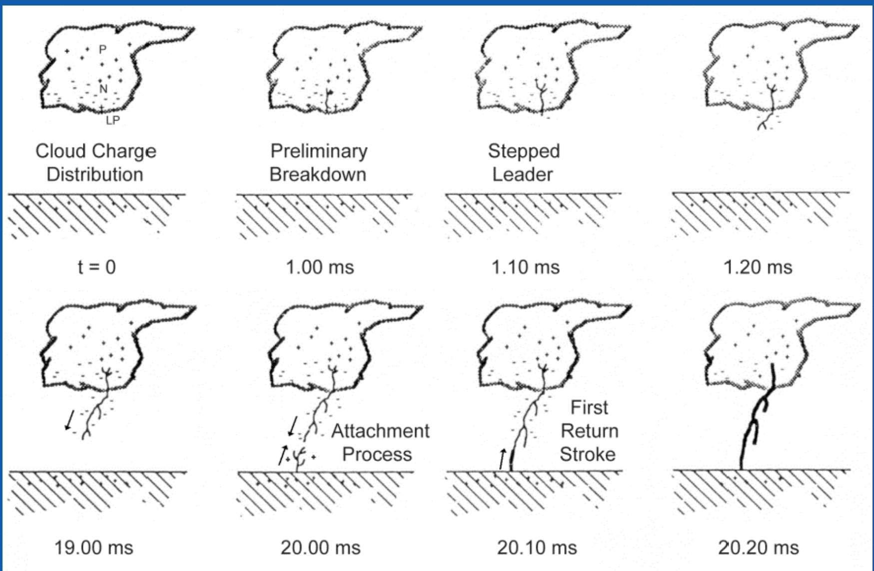


FIGURE 1: some of the processes during a typical downward negative cloud-to-ground lightning flash.

Lightning is a poorly understood phenomenon. Although lightning science can be traced back to Benjamin Franklin, it is only recently, due to the advent of high-speed cameras and electronics, that we have been able to make any significant progress. Even with modern technology, lightning can still be very difficult to study due to its random nature, complex structure, and location in the atmosphere.

Cloud-to-ground flashes

Figure 1 shows some of the processes during a downward negative cloud-to-ground lightning flash, one of the most studied and best understood kinds of lightning. It is called a 'downward negative cloud-to-ground' lightning flash because it connects between a cloud and the ground (vs. not connecting to the ground at all), "negative" because it lowers negative charge to the ground (vs. lowering positive charge), and "downward" because this type initiates in the cloud and propagates to ground (vs. initiating near ground and propagating up to the cloud). In the beginning of the lightning flash, there is a distribution of negative and positive charge within the thunderstorm. When the electric fields in the thundercloud get strong enough, and some other conditions discussed in the next paragraph are reached, then a region of air will undergo dielectric breakdown and become conductive. This region of conducting air will then elongate into a long thin channel of conductive plasma called a stepped leader. A leader is a long self-propagating spark, and this particular kind of leader doesn't propagate continuously but instead propagates through jumps, called steps. Each step can be around 50 meters long. This stepped leader then begins to propagate towards ground, storing negative charge around it in a region known as the corona sheath. When the leader approaches the ground there is an attachment process where small positively charge leaders are emitted from the ground and propagate up to the negative leader. When the downward negative leader and upward positive leaders connect, suddenly there is a conducting path between all the negative charge and the ground, and all the negative charge begins to rush into the ground in a giant current wave known as the return stroke. The return stroke releases a large amount of energy in the forms of light, heat, and sound, which is what casual observers see and hear when lightning occurs.

Two Hypotheses

While these processes may seem straightforward, there is a significant amount of detail missing in our understanding of this picture. Firstly, we do not know how electric charges are generated inside a thunderstorm or what the strength and shape of the electric field is once this distribution is generated. We also do not understand how lightning is initiated in the cloud (called Preliminary Breakdown in Figure 1). There are two major competing hypotheses to explain lightning initiation. One hypothesis claims that cosmic ray air showers can seed secondary electromagnetic avalanches that can grow strong enough to create a conducting plasma (under influence of the thunderstorm electric field). The other claims that small ice and water particles can enhance the electric field enough to allow for lightning initiation. Both of these hypothesis require electric fields larger than what is actually observed. We do not understand how leaders propagate or why this particular kind of leader steps. We have very little information on the attachment process between the negative leader and ground, and we do not really understand the distribution of current with height along the lightning channel during a return stroke.

The Lightning Mapping Array

One of the primary instruments that lightning scientists use to answer these questions is called a Lightning Mapping Array (LMA). A LMA consists of about 8-20 stations, where each station has a computer and an antenna, with kilometers of separation between the stations. Each station records the time and amplitude of radio frequency pulses. Since the positions of the antennas are known, it is then possible to solve the spherical wave equation and find the time and location of the lightning process that made these pulses, as shown in Figure 2. If this equation is applied to hundreds of events then one can build up a four dimensional map of

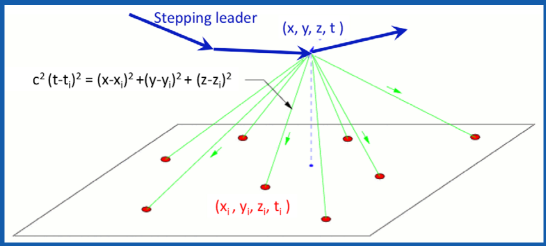


FIGURE 2: certain lightning processes, a stepped leader in this case, produce a radio frequency pulse that can be observed by antennas on the ground some time later. The spherical wave equation can then be used to find the location and time of the event that produced the pulse.

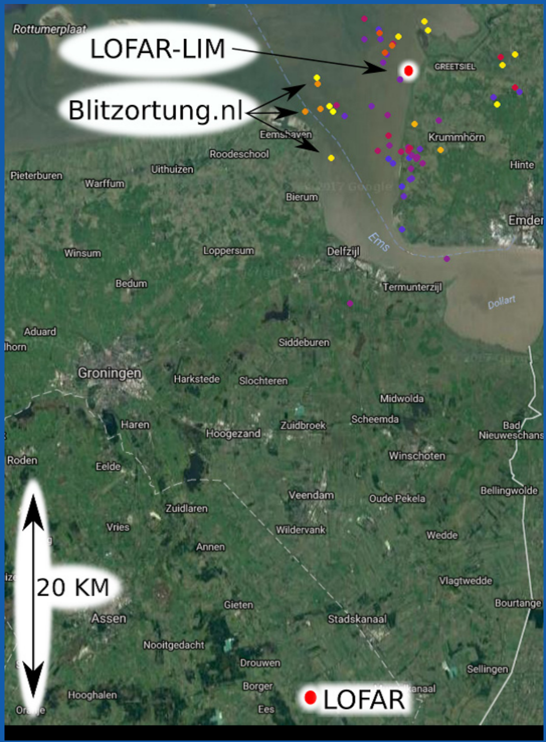


FIGURE 1: a map with a red dot at the bottom showing the location of the LOFAR core and a large red dot at the top-right showing the location of our located lightning flash. There are also a number of smaller colored dots showing the locations of lightning flashes according to Blitzortung.nl.

the lightning flash.

At KVI-CART we are improving upon the LMA concept by using the LOw Frequency ARray (LOFAR) radio telescope located in the North of the Netherlands. By using LOFAR to map lightning we will achieve numerous advancements over typical LMA systems, including having an order-of-magnitude improved resolution and timing accuracy. Figures 3 and 4 show our most current results applied to a lightning flash that occurred on the 19th of June 2013. Figure 3 shows a slice of Google maps with a large red dot on the bottom, showing the location of the LOFAR core. At the top right Figure 3 there are a number of colored dots showing the locations of lightning flashes at this time, according to Blitzortung.nl. The large red dot shows the lightning flash that we were able to locate. Figure 4 shows the same flash, but zoomed-in to show the structure of the lightning flash. Each dot shows the location of each event, and all the events together form the flash. The dots are colored by time. The top plot in Figure 4 shows the altitude vs. time. The central plot shows a top-down view of the lightning flash. The plot to the right shows altitude vs. distance north from the LOFAR core for each event. The plot just above the center shows altitude vs. distance east from the LOFAR core. From this figure we can see that this is an intra-cloud lightning flash, as the lowest altitude is 7 km and the flash does not reach down to the ground. This figure also shows significant structure inside of the flash, but we are not yet convinced that this structure is physical and not a result of noise.

Conlusion

There is still much work to be done before LOFAR can be used to learn more about lightning, such as finding the best way to display the information, using the polarisation information of the pulse to find the direction that charge is flowing during the event, and researching how to efficiently analyse the data when there are a large number of pulses (such as when a lightning flash is close to the LOFAR core). But if we are successful, then the Netherlands will be in possession of the most precise instrument ever used to study lightning, and will be in a position to answer some of the most fundamental questions in lightning science•

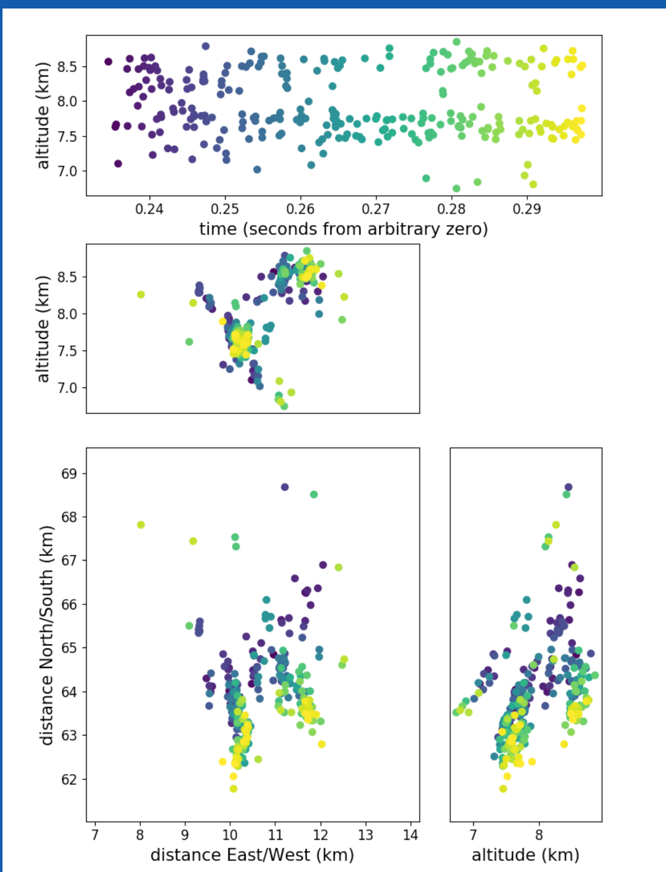


FIGURE 4: a number of dots in X, Y, Z space and time. Each dot represents the location and time of an event during this lightning flash. All together these dots show the general shape of the lightning flash.

Global Geometry of Physical Systems and its Quantum Manifestations

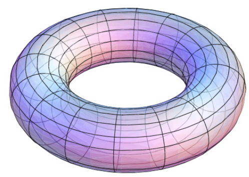
Looking at geometric properties of physical systems from a global point of view reveals a rich geometric structure which can be described using ideas from differential geometry and algebraic topology [1]. These geometric properties are relevant to physical systems as fundamental as the hydrogen atom and, even though they arise in the context of classical mechanics, they have significant implications for the corresponding quantum system.

AUTHOR: **DR. KONSTANTINOS EFSTATHIOU**

To describe the main ideas that come into play in this research direction I will focus on the example of the spherical pendulum. At first sight, the spherical pendulum is not a very intriguing system. It is integrable, that is, the differential equations describing its motion can be solved in terms of known (but non-elementary) functions[1]. And you could reasonably ask, if we can find all motions, then don't we know everything about the system? Well, not quite. Looking at individual motions is like looking through a microscope and may lead to missing the whole picture. There are questions related to global properties which can be answered only if we take a step back and look at the system from a more abstract point of view.

The integrability of the spherical pendulum is not just a happy accident. It has a much deeper reason, related to the existence of two conserved quantities[2], the total energy

$$E = \frac{1}{2}(\dot{\theta}^2 + \sin^2\theta\ \dot{\phi}) + \cos\theta,$$



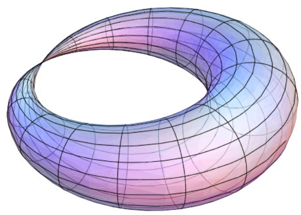


FIGURE 1: Two-dimensional torus T^2

FIGURE 2: Pinched torus. The pinch point corresponds to the unstable equilibrium of the spherical pendulum. The rest of the pinched torus corresponds to motions that are asymptotic to the unstable equilibrium, that is, they "reach it in infinite time."

and the (vertical component of the) angular momentum

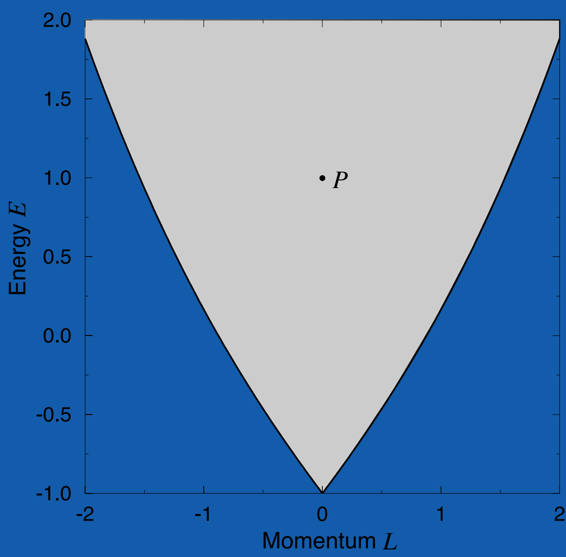
$$L = \sin^2\theta\ \dot{\phi}.$$

Here we are using spherical coordinates where $\theta \in [0, \pi]$ is the inclination angle, $\phi \in [0, 2\pi]$ is the azimuthal angle, and a dot denotes the corresponding time derivative. A very famous theorem in classical mechanics, the Liouville-Arnold theorem, states that the existence of these integrals (together with some technical conditions) implies that the system is integrable. Moreover, the same theorem allows us to make a first step toward a global description of an integrable system. Applied to the spherical pendulum,

1 Notice the contrast with chaotic systems where it is not possible to solve the equations of motion.

2 And there is an even deeper reason: the conservation of the energy and the angular momentum is related to symmetries of the system through Noether's theorem.

FIGURE 3: Bifurcation diagram for the spherical pendulum. Each point in the gray area corresponds to a T^2 in phase space. The point with $(L = 0, E = 1)$ corresponds to the stable equilibrium. The point P with $(L = 0, E = 1)$ corresponds to the pinched torus. Each point along the sides of the diagram corresponds to a horizontal motion of the spherical pendulum. The white area represents combinations of energy and angular momentum that cannot be attained in the spherical pendulum.



it states that for most choices of values of (L, E) the points $(\theta, \phi, \dot{\theta}, \dot{\phi})$ in phase space with the given (L, E) form a torus T^2 (Figure 1). Consequently, all motions with these values (L, E) lie on the same torus.

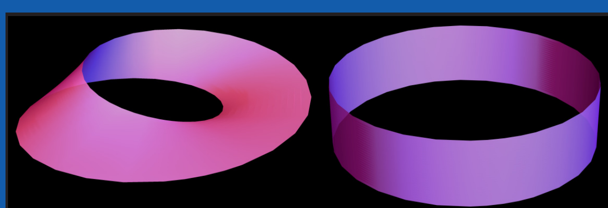
There are some exceptions to having tori. The most relevant one for this discussion is the unstable equilibrium, where the spherical pendulum at its topmost point is motionless with $\theta = 0$, implying $(L = 0, E = 1)$. The set of all points in phase space with $(L = 0, E = 1)$ form a pinched torus (Figure 2). The bifurcation diagram (Figure 3) shows the values (L, E) corresponding to tori (gray area), the exceptional value $P = (L = 0, E = 1)$ corresponding to the pinched torus, and other exceptional cases. This diagram and the associated information is something that one cannot easily deduce by staring at complicated algebraic expressions of the motions. Here, the general theory provides powerful tools to reach these conclusions through qualitative arguments.

The next question from a geometric point of view, and a very natural one for a mathematician to ask, is how all the tori fit together. To understand this question, consider the well-known example of the cylinder and the Möbius band (Figure 4). Even though a cylinder and a Möbius band locally look identical, globally they are very different. Both can be obtained by considering a rectangle, and gluing two opposite sides of the rectangle in different ways[3]. A consequence of gluing the sides differently is that the cylinder is the Cartesian product of a circle and an interval, while the Möbius band is non-orientable and cannot be written as a Cartesian product.

Back to the spherical pendulum, consider a loop L in the gray area in Figure 3. Each point on the loop corresponds to a T^2 in phase space and taking all these tori together gives a bundle of tori over L. Such bundles can be classified through a gluing map: start with the Cartesian product $[0, 1] \times T^2$ and then glue the tori at the endpoints of $[0, 1]$ to obtain the required bundle (Figure 5). The gluing is given by a 2×2 integer matrix with determinant ± 1, called monodromy matrix. The main observation is that the bundle of tori is a Cartesian product $L \times T^2$ if and only if the monodromy matrix is identity. In the spherical pendulum, it has been shown that the monodromy matrix for a loop L going once around P is

$$\begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix},$$

FIGURE 4: Möbius band and Cylinder.



3 A very similar example is given by the torus and the Klein bottle where the rectangle is replaced by a cylinder and the two circles at the ends of the cylinder are glued in different ways.

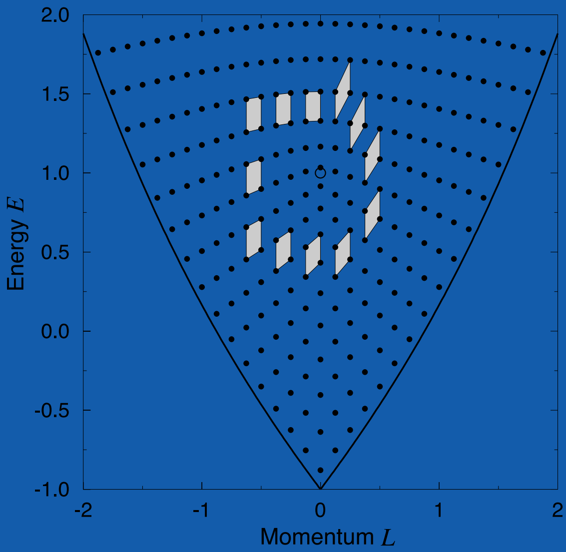


FIGURE 6: Joint spectrum for the spherical pendulum drawn together with the bifurcation diagram. A small cell is moved along a loop around P.

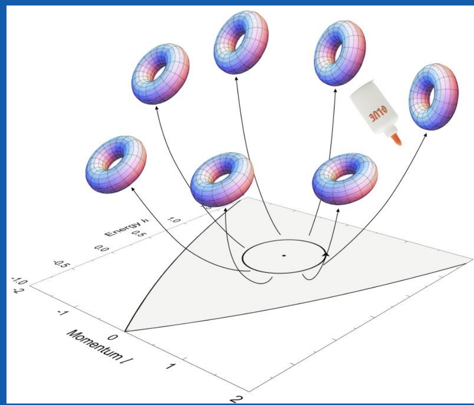


FIGURE 5: Gluing tori to form a torus bundle

implying that in this case the bundle is not a Cartesian product and the tori are glued with a “twist”. We say that the spherical pendulum has non-trivial monodromy [2].

These are few of the things that one can say about the global geometry of the spherical pendulum and there are many more interesting connections that one can make with other deep geometric ideas. For example, we have recently shown that the reason for non-trivial monodromy is that a Hopf fibration is hidden in the neighbourhood of the unstable equilibrium [3].

The non-trivial geometry of the spherical pendulum manifests in the corresponding quantum system. Here one can define the joint spectrum of the two quantum operators that correspond to the energy and the angular momentum (Figure 6). You can see in the joint spectrum that if you take a small cell and you move it along a loop going around P you end up with a different cell than what you started with, a manifestation of quantum monodromy. And if you pay close attention to the difference between the sides of the initial and final cells you can even read the monodromy matrix from this picture! Quantum monodromy has been found in a wide variety of fundamental atomic and molecular systems, for example, the hydrogen atom [4,5], and is important for assigning quantum numbers to experimentally observed spectra.

The study of the global geometric properties of physical systems, both at the classical and quantum levels, reveals intriguing geometric structures and explains the structure of the corresponding joint quantum spectra. Here we have only touched on this active field of research in which the group of Dynamical Systems, Geometry, and Mathematical Physics at the JBI is deeply involved•

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A First-Year's Experience with the FMF and Why You Should Join a Committee

AUTHOR: **ROBERT MOL**

Robert Mol, a first-year Applied Mathematics and Applied Physics double bachelor student, still finds the time for extra-curricular activities. We asked him about his favourite extra-curricular activity: committee work at the FMF!

In my first year at the FMF I joined what we now call "The A-Team", great committee, love it, everyone says so *Trump hand movements*.

Throughout the year I found that doing a committee, and going to activities is one of the best ways to get to know others. Now I know more people than I ever thought I would. So I also joined a second committee, the Math Alumni Day. While we had the Math Alumni Day, photos were of course being taken by our friends from the Fotocie. However halfway through the event, the photographer had to leave. Having nothing better to do, I picked up the camera and made some photos myself, and was promptly asked if I wanted to join the Fotocie as well. Thrilled with excitement, I responded "yea, sure". Being an active member has been the greatest way to make a study more fun. So to anybody who is just a member for the books and happens to accidentally read this, go join a committee. To push the limits of my committee knowledge further, I joined the Symposium committee with a friend of mine. Doing committees really adds something to your days as a student and lets you pick up a very particular set of skills•

FIGURE 1: Robert Mol, pictured here at the FMF's annual Christmas Dinner.

FIGURE 2: A group picture of the FMF's photography committee, the Fotocie. With from left to right Robert Mol, Jip van Ham, Jorn Wildering, Manoy Trip, Martijn Oudshoorn, Emily Mook, and Edward Boere.

AUTHOR: **JOOP ADEMA**

The FMF and BEST

As I was asked to become part of the Local Board of European Students of Technology (BEST) board as a delegate of the FMF, I, like most people at our faculty, first had to find out what BEST actually is and which role it can take in a student's life. According to the website of BEST it was "an organisation aiming to help European students of technology and science to become more internationally minded, by reaching a better understanding of European cultures and developing capacities to work on an international basis."

Four study associations of our faculty founded BEST in 2015, one being the FMF. In 2016 the boards of the associations decided that BEST finally needed its own organisation and a board to lead it.

After a small period of doubt and after listening to some cool stories from the FMF's secretary Sietse Buijsman, I decided to accept the challenge and join the board. However, there's always more to learn than some fancy quote on a webpage can contain. After meeting up with BEST people, joining and participating events and meeting events, the benefits to students became clear to me.

BEST has a vivid international community aiming at optimising the organisation of BEST and the events for students of BEST; so-called internal events are organized to realise this. However, the two major activities BEST offers to students are the seasonal courses (external events) and the engineering competitions. The seasonal courses are seven to twelve-day events on a topic determined by the Local BEST Group (LBG), for which students can apply.

These courses contain lectures, practicals, and company visits, but also international evenings, parties and cultural activities. Excluding your own travel costs, the costs of a course is always less than €45,-, including three meals per day and housing. The yearly Engineering competitions (EBEC) exist of two separate competitions: a case study and a team design. The LBGs organise these competitions, their winners go to the regional round and the winners of that go to the final round at one LBG. Each round consists of a different assignment within a specified topic.

At the beginning of May, our Group in Groningen was voted into Baby Membership, which means that students of our faculty now have all the rights to participate in Seasonal Courses. The General Assembly of BEST was very enthusiastic about the plans and the achievements of our Group in Groningen so far and unanimously chose to promote BEST Groningen.

Nevertheless, the external events are what is interesting to the majority of you. The Seasonal Courses are a great way to gain some more practical experience in an international setting. You'll meet new people, often interested in the same field of studies as you are. This enables you to get a grasp on how it will be to work somewhere else in Europe, to enhance your English language skills, to meet new European people, cultures, and traditions and to make friends all around the continent! From September 17 onwards the new season of courses will be announced and you can apply on the BEST website for Winter Courses!

For the future, our LBG will still be closely tied to the four associations that founded it. However, for an LBG to be persistent, strong support of the associations is necessary, but not sufficient. An LBG is an organisation that deals with similar challenges as the student associations such as fundraising, member management and university relations, but also always has to take into account the international side and the objectives of the entire BEST organization. For this to be managed, LBG Groningen requires a board that faces interesting challenges and obviously requires committees (which we call working groups). Furthermore, as time proceeds, we will start organising larger events, such as a Summer Course in 2018, for which we will be composing an organising team!

The international setting of BEST is a strong motivation for me personally to do a board year in our LBG and I certainly enjoy it, especially when for example a group of members of BEST Leuven is coming to Groningen for the Alphabet party or to participate in a Regional Meeting in Belgium which mostly consisted of serious meetings and trainings. As an active member of LBG Groningen there is always the opportunity to be in contact with people all over Europe, and also to be a delegate for LBG Groningen to BEST meetings, or to randomly co-organise or pass by BEST events!

Of course, if you have any questions or are interested in BEST events or even to become part of BEST Groningen, do not hesitate to take a look at bestgroningen.eu or best.eu.org or to contact us via bestgroningen@gmail.com•

FIGURE 2: The board and advisory council of BEST, From left to right: Duncan Saunders, Joop Adema, Ingeborg van Keulen, Robin Hermes, Tineke Jelsma, Joeri ten Kate, Willeke Mulder, Sietse Buijsman, Jos Borger.

Building a Research Career at ASTRON

Since 2003, I have been working at ASTRON, the Netherlands Institute for Radio Astronomy. However, I could also say that I have been working there since 2002 as my Master's project at ASTRON turned out to be the start of an interesting research career with that institute.

AUTHOR: **PROF. DR. STEFAN WIJNHOLDS**

FIGURE 1: Photos of the WSRT (left), the LOFAR core (middle) and ThEA (right).

ASTRON (www.astron.nl) is an NWO institute whose mission is "making discoveries in radio astronomy happen". Instrumental to this mission is the mixture of expertise that we have within one building: the Astronomy Group provides instrument principal investigators and links to the astronomical community, the Radio Observatory operates and maintains our telescopes (the Westerbork Synthesis Radio Telescope (WSRT, see Figure 1 left panel) and the Low Frequency Array (LOFAR, www.lofar.org, see Figure 1 middle panel)) and the R&D department develops new instrumentation and functionality. For my Master's project, I worked on the integration and validation of the Thousand Element Array (ThEA, see Figure 1 right panel), a phased array technology demonstrator

The phased array phase

Phased arrays are arrays of antennas (in our case usually a large number of them) in which the signal received by each antenna can be delayed to compensate the travel time of source signals from one specific direction across the array as illustrated in Figure 2. This process ensures that signals coming from that direction are added coherently while signals from other directions cancel out in the adding process. ASTRON was (and is) investing heavily in this technology as it has a number of attractive features:

1. As the receiving area of an antenna element scales with wavelength squared, it is more cost effective to construct a large collecting area (crucial to get a large sensitivity) with phased array technology than with the traditional reflector dishes.
2. Phased arrays are very adaptable: one can form multiple beams simultaneously, thereby increasing the instantaneous sky coverage and, as steering is done electronically, the telescope can be repointed from any position on the sky to any other position in the sky almost instantly.
3. The array elements have an extremely wide field-of-view (potentially all-sky), giving phased arrays great potential for monitoring of transient phenomena.

During my internship, I managed to successfully demonstrate that ThEA could perform astronomical observations up to the rest frequency of atomic neutral hydrogen (1420.4 MHz) by making an all-sky map of the hydrogen in our Galaxy. As I enjoyed this project a lot, I asked Jaap Bregman, my supervisor at ASTRON, whether there were jobs available at ASTRON. At that time, ASTRON was making strides towards the first LOFAR prototype stations and could use somebody who could do similar integration and validation tests like those I had just done with ThEA, so this request resulted in a job offer. Hence, here's advice number one:

An internship or Master's project can land you a job, so you may want to start thinking about what you want to do after graduating before starting such a project.

Going pro

Hence, I started working on testing LOFAR prototype stations. During those first years of my career, I developed a mentor-mentee relationship with Jaap Bregman. This has been very valuable. First of all, for all the technical experience he had to share, but also for his guidance on work related matters and developing a career. This brings me to my second advice:

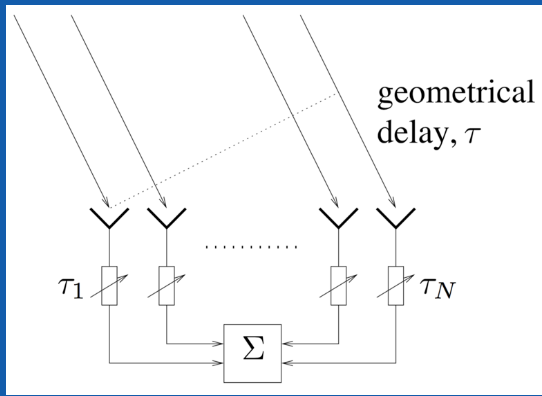

FIGURE 2: Block diagram of a phased array

If there is an opportunity to develop a mentor-mentee relationship with a senior colleague, take it!

One of the main challenges I was confronted with during tests with the LOFAR prototype stations was

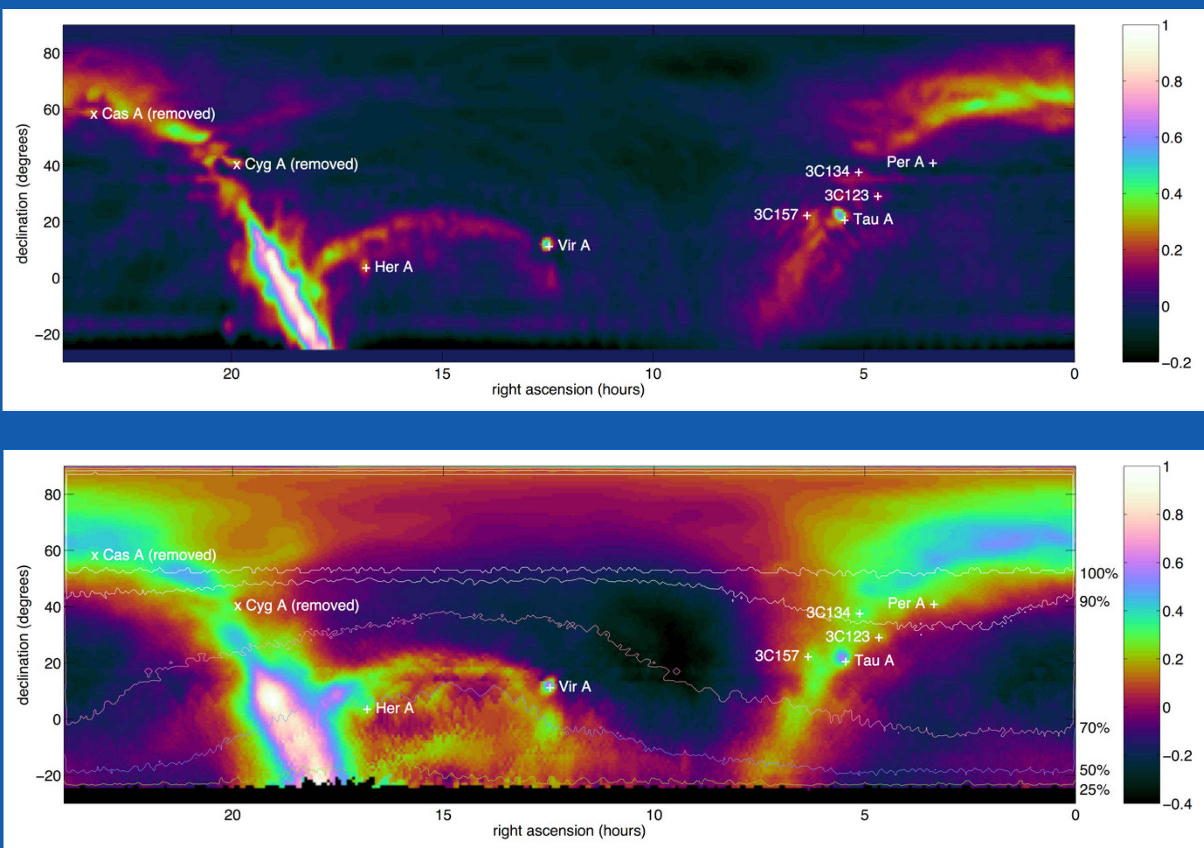

FIGURE 3: Map made with the first full-size LOFAR prototype station (top) and with the last prototype station before production (bottom) showing the impact of advances in the post-processing of the data.

calibration of those stations to ensure that the incoming signals were accurately aligned (a rather crucial aspect for a phased array!). At some point, I gave a presentation about the status of my work on calibration during a seminar at ASTRON. One of the people in the audience was Alle-Jan van der Veen, a professor specialised in array signal processing at the Delft University of Technology, who approached me after the seminar concluding that I did all sorts of interesting things and that, perhaps, we should discuss those further. I accepted his invitation and that discussion ultimately escalated into a PhD project, in which I not only worked on calibration issues, but also on the removal of the instrumental response of the phased array station. The impact of using advanced signal processing techniques for image reconstruction is nicely illustrated in Figure 3.

PhD, is it a good idea?

Interestingly, I did not set out on my career with the intention of getting a PhD. However, as Alle-Jan put it, if doing research is a natural trait of someone, it does not matter where you put that person to work as it will result in research being done. However, after obtaining my PhD, I did notice that having a PhD does matter to others, in particular in academia, where it really opens new doors. Hence, my third advice is:

> *If you want to build a career in academia or in a research environment closely connected to academia, get a PhD!*

After receiving my PhD, the main focus of my work shifted from development of new signal processing tools for calibration and imaging to understanding the fundamental limitations of phased array systems. At the same time, my focus also shifted from LOFAR to the Square Kilometre Array (SKA, www.skatelescope.org), which is currently in its design phase. As the SKA is a big international project, I naturally got involved in a number of international collaborations with fellow researchers and I got the chance to build an international network of peers. One of those collaborations even resulted in an appointment as extraordinary associate professor at the University of Stellenbosch in South Africa.

With great expertise comes great responsibility

An advantage (and disadvantage at the same time!) of becoming an internationally recognised expert is that a relevant track record gives you authority. This makes it easier (sometimes too easy!) to convince other people of your views. From practical experience with less-seasoned project managers, I can testify that relevant subject expertise also helps when taking up management roles. Based on this experience, my last bit of advice is:

> *Even if you want management responsibilities in a research environment, first strengthen your subject expertise.*

While building that expertise, you will experience the good, the bad and the ugly of (project) managers as I did and you will still have plenty of time left in your career for your managerial ambitions. To put things in perspective: I can already call myself professor and I have not even reached the age of 40!

FIGURE 3: Artist's impression of the offset Gregorian antennas of the Square Kilometer Array, which will be built in South Africa and Australia.


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From the Board

AUTHOR: **THOMAS SWARTS**

This year, Thomas was the Commissioner of External Relations for the FMF. In this article, he tells us about his experiences.

It was 7-ish AM on a Tuesday when I stared dully at my reflection in the window of Groningen Central Station's AH to-go. The person gazing back at me was wearing an all-black suit, polished black shoes, a half tucked-in white shirt and a worn out expression on his face that spoke volumes about burning the midnight oil. Displeased with the sight he turned to the counter and ordered a black coffee. "Have a nice day", the cashier said as she handed me the drink. "No thank you", I replied and started for the exit. Though realising my error, I backed the reply by walking into one of the customers, spilling a significant portion of the hot liquid on my hands in the process. I thanked the stars my company meeting was 2 hours away as I strode for the train. Catching it with 3 minutes to go until departure I ended up in a compartment with fellow travellers looking as ravishing as myself. Found myself a seat, and listened to the snoring symphony backed up by the steady ascending rhythm of the speeding train and soon contributed to the brass section of its drooling orchestra.

I'm no early bird, as may be inferred from the above. However, mornings like these weren't unusual for my board year. On the plus side, I got to see a lot more of the Dutch countryside. That said, I don't want to give the impression that my prime pursuits were public sleeping and exploring the rural parts of the Netherlands, which is only partly true. What defined my board year above everything was the substantial number of career-related activities I had to arrange, luckily together with a highly enthusiastic and capable Huygens committee. In the past year we successfully organised twenty career related lectures, six inland excursions, several other company activities and at the top of the bill, a one-week long excursion to Ukraine, making my year so far quite a busy one, but also very rewarding.

And a busy year it has been, for all of us. You start your week juggling three responsibilities, but before you know it you are going from a three to four to five to six ball cascade. Maybe the most exemplary has been the efforts of our commissioner of education; new initiatives like our course related excursions, the high number of academic lectures and our involvement in the annual physics conference "FYSICA" effectively improved the cooperation between our association and the university.

That said, in the end, our year as a whole has been mostly defined by the time and efforts more than eighty enthusiastic members put into organising activities and supporting our association. To them, and to the five highly functioning alcoholics that worked by my side and still do I say; thanks for the great experience•

FIGURE 1: Thomas during the yearly Christmas dinner.

Quench that Thirst

AUTHOR: CAROLIEN FEENSTRA

Imagine yourself strolling around in the searing summer heat and craving just one thing: a beer that is tasty, relaxing and refreshing at the same time. In a study conducted in 1998 Guinard et al. attempted to find the perfect formula for a refreshing, thirst-quenching beer [1].

The researchers determined which sensory attributes influenced the thirst-quenching properties of the drink, both positively and negatively. They found the most highly carbonated beers and those with a high bubble density to be the most refreshing. Other factors as foam, overall aroma and flavour and sensory properties as bitterness and acidity were determined to decrease the beer's capability to relief your thirst. Below are three recipes that take the aforementioned into account and are still tasty and delicious. Enjoy!

Dublin Iced Coffee

Ingredients:

- A cup of strong coffee
- A cup of stout (such as Guiness)
- A shot of whiskey (optional)
- Whipped cream or milk
- Ice cubes

Put some ice cubes in a tall glass. Pour the whiskey in the glass, follow with the coffee and subsequently add the Guiness. Top off with some whipped cream. (For the whipped cream, whisk 250 ml with 3 tablespoons of sugar until the cream is smooth and thick yet runny.)

Beermosa

Ingredients:

- 4 shots of orange juice
- Bottle of cold wheat beer (witbier)
- Optional: a shot of bitters (s.a. Beerenburg, Amaro or Cointreau)

Put some ice cubes in a tall glass. Pour the whiskey in the glass, follow with the coffee and subsequently add the Guiness. Top off with some whipped cream. (For the whipped cream, whisk 250 ml with 3 tablespoons of sugar until the cream is smooth and thick yet runny.)

Dutch Ginger Beer

Ingredients:

- A glass of ginger ale or ginger beer (+/-150 ml)
- A shot of brown Dutch gin (bruie jenever or Beerenburg)
- A lime
- Icecubes
- Optional: a shot of apfelkorn

Fill a glass with some ice cubes. Add a shot of Dutch gin and squeeze half a lime in the glass. Add the ginger ale or ginger beer. Cut the other half of the lime in pieces and add to the drink. For a sweeter and fruitier flavour add a bit of apfelkorn (apple liqueur)•

References

[1] Guinard, J. et al. (1998), Determinants of Thirst-Quenching Character of Beer. *Appetite,31(1),* 101-105

Brainwork: Symbolic Square

AUTHORS: **JOHAN JAGER** AND **HELENA JAGER**

Each square is either TRUE or FALSE. If a square is true, then all statements in that square are true. Similarly, if a square is false, all statements in that square are false. Each square has exactly one symbol. (Either **κ**, **λ**, **π** or **τ**). These symbols can help you identify properties of the square. Your task is to find out for all squares whether they are TRUE or FALSE and which symbol they have. Adjacent squares include diagonals.

all squares in this column are false. There is at least 1 true corner square.	The square directly to the right has a **τ** or **π** symbol. The bottom row has more squares with **κ** symbols than squares with **λ** symbols.	The difference between the total number of **π** symbols and **κ** symbols is exactly 1. There is no square with a **κ** symbol that is adjacent to exactly 3 squares with a **λ** symbol.	This square has a **π** symbol.	This Square has no **π** symbol. The square directly below has a **τ** or **π** symbol.
This square has a **λ** symbol.	This square is adjacent to at least 1 square with a **τ** symbol. Directly to the right of each square with a **λ** symbol must be a TRUE square.	There is at least 1 **κ** symbol in the bottom row. This square has a **κ** symbol.	The square directly below has a **π** symbol. Squares directly to the right and left have the same symbol.	There is exactly 1 **π** symbol in the bottom row.
Every square adjacent to a square with a **π** symbol and a square with a **λ** symbol is TRUE. This square has a **π** or **κ** symbol.	There are exactly 6 adjacent TRUE squares.	There is no **λ** symbol is this row.	Squares directly to the right and left are TRUE.	There is no **κ** symbol in this row.
This square has a **λ** symbol.	The square directly above has a **τ** symbol. Every column has at least 1 TRUE statement.	There are exactly 7 squares with **τ** symbols.	The square directly to the left has no **λ** symbol. The square directly below has a **λ** symbol.	Every column has exactly 2 **π** symbols.
Some corner squares share the same symbol. This column has all 4 symbols.	Each row has at least 3 different symbols.	Every square with a **κ** symbol is adjacent to at least 1 FALSE square.	Every column has exactly 2 **κ** symbols	There is a square with a **τ** symbol in this row

Solution to Previous Brainwork: The Praeses II

Let the speed of the Praeses be v(t). Consider the time interval when a mass dm enters the Praeses. Conservation of momentum gives:

$$(dm)u + mv = (m + dm)(v + dv)$$
$$\Rightarrow dm(u - v) = mdv,$$

where we have dropped the second-order dmdv term. Separating variables and integrating gives

$$\int_M^m \frac{dm}{m} = \int_0^v \frac{dv}{u-v} \quad \Rightarrow \quad \ln\left(\frac{m}{M}\right) = -\ln\left(\frac{u-v}{u}\right)$$

$$\Rightarrow m = \frac{Mu}{u-v} \quad *$$

Note that m approaches infinity as v approaches u, as it should. How does m depend on time? Mass enters the Praeses at a rate k(u-v)/u, because although you throw the beers at speed u, the relative speed of the beers and the Praeses is only (u - v). Therefore,

$$\frac{dm}{dt} = \frac{k(u-v)}{u}$$

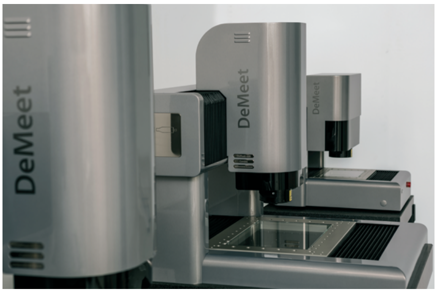
Substituting the m from $*$ into this equation gives

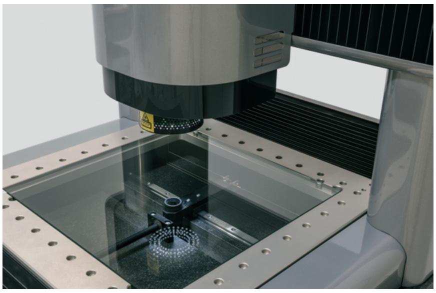
$$\int_0^v \frac{dv}{(u-v)^3} = \int_0^t \frac{kdt}{Mu^2}$$
$$\Rightarrow \frac{1}{2(u-v)^2)} - \frac{1}{2u^2} = \frac{kt}{Mu^2}$$
$$\Rightarrow v(t) = u\left(1 - \frac{1}{\sqrt{1+\frac{2kt}{m}}}\right)$$

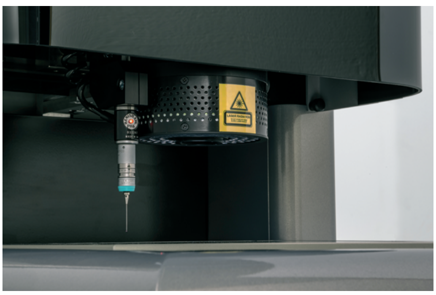
Note that v approaches u as t approaches infinity, as it should. Integrating this speed to obtain the position gives

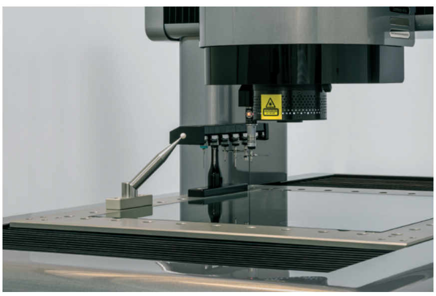
$$x(t) = ut - \frac{Mu}{k}\sqrt{1+\frac{2kt}{M}} + \frac{Mu}{k}$$

We see that even though the speed approaches u, the Praeses will eventually be an arbitrarily large distance behind a beer with constant speed u. For example, pretend that the first beer missed the Praeses and continued to travel forward at speed u.









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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***.

Je bent bij ons van harte welkom voor een oriënterend gesprek of een open sollicitatiegesprek of overleg over de mogelijkheden van een **stage-** of **afstudeerproject**. Wij raken graag in contact met gemotiveerde en talentvolle studenten.

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