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IN THIS ISSUE

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Part I

Proceedings of IAPS

Editor's Note

Welcome to the ICPS 2017 issue of the journal of the International Association of Physics Students (jIAPS). This issue will cover a subset of the submitted articles in the academic year of 2016/17.

In this year's issue, you will find different scientific articles written by students about their research and physics in general which they find interesting. A main focus is on articles about activities organised by IAPS and our member organisations as usual.

The editorial team of jIAPS and the executive committee of IAPS would like to congratulate Mario Gaimann from the University of York, UK, for winning the jIAPS Article Contest 2017 with his article about surfaces and interfaces on an atomic scale and the emerging field of spintronics. Find it at the beginning of the scientific part on page 15.

I hope you have a good time reading the 2017 edition of jIAPS!

Moeen Ghafoor
Editor-in-Chief

President's Letter

Dear reader,

If you are seeing this, you have gotten your hands on the annual journal of the International Association of Physics Students! Celebrating our 30th anniversary this year, we consist of students spread all around the globe, but we are all working together with the common goal of making the world a better place for physics students.

This year has seen new member committees in Spain, Stockholm, Zurich, Belgrade, Kathmandu, and New Delhi, and our largest outreach event – the School Day – has been held on three continents! Students have been aided in their stay abroad by the IAPS Contact Network while the FERMI database helped them choose where to go.

Our network has been strengthened and extended internally thanks to our Student Ambassador Programme as well as externally with new sponsorship opportunities.

As usual, we have hosted and supported several events for students throughout the year. It all began with the yearly exchange event of our national committees of Germany and Hungary followed by *iaps4FUSION*, where our British friends invited us to see their nuclear fusion facilities in Oxford.

NC Italy invited us to learn about optics during *Lights of Tuscany*, with *Wendelstein Seminar* we had another fusion-themed event – this time in Germany – and not to forget *iaps2CERN* which is organised yearly by IAPS.

Larger than the other events has been the competition in theoretical physics – PLANCKS – which NC Austria held in Graz this May. With 20 participating countries and 36 participating teams, this was the largest edition held since its inception in 2014.

But the largest event is the International Conference of Physics Students 2017. Our NC Italy has been working hard for the last two years to welcome us.

In short, you are not just holding an ordinary journal but rather a piece of a vibrant community of physics students.

Enjoy!

Henrik Siboni

Henrik Siboni
President of IAPS

Autumn School 2016 – Berlin

Since the very first exchange event in Budapest, Hungary back in the autumn of 2013, The Young German Physical Society (NC Germany) and Mafihe (NC Hungary) have established an annual meeting with alternating host.

Having taken place in Munich (2014) and at Lake Balaton (2015) it was up to Germany to host the great event in 2016 again. Therefore, 36 students from Germany, Hungary and some other IAPS member committees visited Berlin on September 8th to 11th.

The German capital doesn't only impress with its turbulent history and architecture, but also with different universities as well as several prominent research institutions. This leads to a huge variety of the different most topics to be covered during the four day programme.

To get to know each other, the autumn school started with breaking the ice and some finger food in the garden of the Magnus-Haus Berlin in beautiful late summer weather. The scientific programme started with an invited talk by Maria Krikunova who is a professor at Technical University of Berlin on the topic of ultra-fast physics – one of the specialties of the German capital – which gave the participants a great insight in a very interesting field of physics and a topic for conversation for the rest of the day.

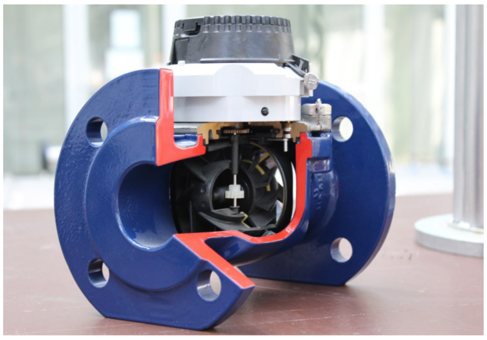
First excursion guided us to the Institute for Planetary Research of the German Aerospace Agency. The scientists were really happy – on one hand for having young and interested students visiting and on the other hand because of finding the lander Philae of the Rosetta Mission on top of comet 67P/Churyumov-Gerasimenko earlier that week.

Further insight in the life of a researcher was given by a Hungarian researcher, who explained techniques to search for and find new planets somewhere deep in the universe. The highlight of the visit definitely was a virtual 3D flight through the canyons of our red neighbour – the Mars – which was produced out of real data collected by several orbiter missions.

Different missions and experiments could also be seen in the huge building just across the street where we could visit the synchrotron BESSY. While walking through big halls and having the opportunity to take a look at different experiments like investigation of surfaces concerning absorption of water, some researchers explained the fundamental physics behind synchrotron radiation.

Another point on the agenda was the visit to the German metrology institute – the Physikalisch Technische Bundesanstalt (PTB). Even though it was Saturday, researchers and PhD students working there came to guide us around the Institute and show us their work.

This gave us an interesting view of their mission and cooperations. During the lab tour we visited the room with the lowest magnetic field on earth, the facilities of the medical physics section and a setup to determine the flow of gases and liquids.



To complete the diversity of the event's programme, some participants were selected to give a talk about their field of research or just a topic of their interest on Sunday morning.

We thank IAPS for kindly supporting the exchanging Autumn School between NC Germany and NC Hungary with the IMAP Grant as well as the German Physical Society.

We hope to continue with the cooperation for the next couple of years. In addition, we hope to expand IAPS programme with more exchanges in the upcoming years.

Wiebke Hahn
Tobias Messer

Wiebke is doing her Master studies in the field of semiconductor physics at École Polytechnique in Paris; Tobias is doing his Master studies in the field of optics at the Karlsruhe Institute of Technology. In addition, he is board member of the jDPG and IAPS.

IAPS members visit the UK – iaps4FUSION

The University Student Network based in the UK hosted another edition of the popular fusion and plasma physics event "iaps4FUSION". This event focuses on research groups and industries that are at the forefront of fusion energy.

22 enthusiastic physics students ranging from undergraduate to final year masters, from the UK and abroad, swarmed to Oxford anticipated and excited for the next few days. The trip kicked off with talks and lab tours at the Clarendon Laboratory at Oxford University.

We had some technology issues at the beginning of the talks which meant some of the professors reverted back to chalk and board to explain their work. However, this only added to the experience and was more exciting than our standard PowerPoint lecture.

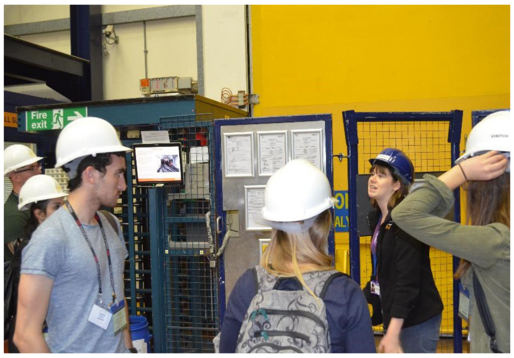
After the talks, we had a chance to speak informally with some of the best minds in fusion research whilst groups split off to visit some of the labs. This was a perfect opportunity for anybody wanting to study at Oxford to get first-hand information about research at one of the top institutions in the world. Participants also enjoyed some free time exploring the city. We finished the evening off dining together, which was a great opportunity for everyone to get fully acquainted.

Spirits were high the following morning as we headed to the Culham Centre for Fusion Energy, which is home to the largest fusion reactor in the world, the Joint European Torus (JET).

This experimental reactor works on the principle of magnetic plasma confinement. The CCFE also hosts the UK fusion facility, MAST, and is leading the way towards the completion of the international fusion reactor. This was a fantastic insight into the forefront of fusion research. We were shown around the facility and had a chance to speak with researchers about all the exciting opportunities available.

That evening, we headed to the British capital for a relaxing night socialising and dining before another big day visiting more institutions. The morning was spent exploring the Natural History and Science Museum which hosted fantastic exhibitions ranging from history and botany to physics and astronomy and everything in between.

Later that day we headed to Imperial College London for lunch followed by talks in the shock physics department. Afterwards, we headed to various labs to be shown current projects. Each lab was hosted by an expert in that particular field who guided us through what was going on.



Once all the tours had finished, we met again in the shock physics department where cake and coffee awaited us, for an informal gathering with lecturers and researchers.

This gave everybody a chance to talk about opportunities and upcoming PhD positions.

The remainder of the evening was spent winding down over dinner, some participants left early to catch various travel arrangements whilst the remainder enjoyed their last evening together.

This trip was a great success in many ways. A few of the participants are actively seeking opportunities in fusion energy, with some pursuing PhDs in this area. This goes to show that inspiration can come at any point, from anywhere, even when you're having fun!

I hope to see more IAPS members from farther afield in 2017, our next edition of iaps4FUSION is planned for late August. This time, we hope to have around 30 to 35 participants. Check out @IOPUSN on Facebook or follow us @IOP_USN on Twitter, or email us at usn@iop.org to find out more.

Benjamin Cowan

Benjamin is a former Royal Marines Commando who left the armed forces to pursue physics. Currently, he is a 2nd year undergraduate student in physics and mathematics at the Open University.

Lights of Tuscany 2016

Are you interested in Laser Physics? Is your dream the search for Gravitational Waves? Do you want to work on the coldest states of matter? Do you like the beautiful landscapes and history of central Italy? This and much more has been possible for the 40 participants of Lights of Tuscany 2016.

The event, organised by the Italian Association of Physics Students and open to all IAPS members, took place from the 15th to the 19th December 2016 in Pisa and Florence. The participants from seven different countries were able to visit some of the most advanced laboratories and research centres and enjoy some talks by the Professors and Researchers of the Universities of Pisa and Florence.

The first visit was at the European Laboratory for Non-Linear Spectroscopy (LENS) and the University of Florence where light is used in particular to study Bose-Einstein condensates,

fundamental aspects of quantum mechanics and other very exotic studies. At the University of Pisa the participant were able to visit the laboratories specialised in laser cooling systems and crystal growth, then they had the chance to visit the Michelson interferometer VIRGO at the EGO-VIRGO site.

The VIRGO group participated in the analysis of the signals found by the LIGO interferometers which showed the existence of gravitational waves and is going to start to collect data with the advanced configuration by the end of 2017. After a full free Sunday in Florence the group was split in two parts for the last day in Pisa: one part went to the National Institute of Optics facility at the National Research Centre area, the others investigated the nanoscale at the National Enterprise for nanoScience and nanoTechnology, one of the most advanced facility of the Scuola Normale Superiore.

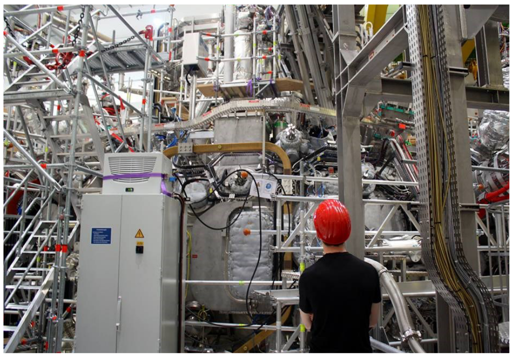
It has been a great event and as the main event organizer I would like to thank all the participants and remind you that the Italian Association of Physics Students will be glad to welcome all IAPS members to its other international events, such as the Particle and Astroparticle Physics Autumn Program in October.

Marco Morrone

Marco is a student of the University of Pisa and member of the executive committee of the Italian Association of Physics Students.

Bringing the stars to earth – Wendelstein Seminar

The young DPG (NC Germany) organises a diverse scientific programme for students, high school students and PhD students.



During the last decade, an annual programme consisting of excursions, seminars for undergraduate students as well as workshops on theoretical physics was established. While most of those activities are addressed to students from Germany, the international programme of jDPG has been growing for the last couple of years.

Not only ICPS 2014, but also the annual exchange with Mafihe (NC Hungary) brings together students from different countries. A similar programme with AISF (NC Italy) will be launched this year. These joint events are focusing on the exchange of the participants and of giving a wide overview about the pyhysics landscape of the host city.

Now, we made the next step and organised the first international seminar giving students the opportunity to deepen their knowledge in a recent research topic within an international atmosphere. For this we chose a scientific project of international importance – Wendelstein 7-X – developed at the Max-Planck-Institute for Plasma Physics (IPP) in Greifswald at the coast of the Baltic Sea.

Wendelstein 7-X is the largest Stellarator in the world and focuses on making fusion energy available and building the first economic fusion power plant. To reach this goal, mainly two concepts of reactors are investigated: the *Tokamak* on one hand and the *Stellarator* on the other hand.

More developed at the moment is the Tokamak concept – you might know ITER which is currently under construction and which will be the first fusion reactor supposed to produce more energy than it consumes. However, the Tokamak brings a large disadvantage which might be fixed by the Stellarator: It can only perform puldsed operations due to conceptional reasons.

The Stellarator, however, does not have this problem – in theory. This kind of reactor is supposed to perform steady state operations. This comes at the price that the shape of a Stellarator is way more complicated than that of a Tokamak what is the reason why in the past the Tokomaks were developed much faster. And that is the mission of Wendelstein: It was built to show that steady state operation is possible, even if it is still too small to produce a significant amount of energy.

Core of the seminars programme were scientific lectures ranging from the basics of plasma physics to resent research topics. The particular focus was on Wendelstein of course, but also the physics of a Tokamak was introduced. Hightlight for many participants was for sure the tour to the Wendelstein installations during the final preparations of the second run.

We also explored the unexpected wide range of plasma physics applications in our all day life during an excursion to the Leibniz Institute for Plasma Science and Technology. The last afternoon was spent at the former nuclear power plant in Lubmin.

There we had the very rare chance to visit a fully installed but never used nuclear reactor where we could take a look into a real nuclear reactor and visit the usually impassable areas of a nuclear power plant. On the last day, four participants took the chance to present their own research during the student talk session.

The expectations of the 40 participants from ten different countries were notably satisfied. Especially the concept of a seminar with international participants was very positively mentioned in the evaluation. The seminar was a great success and the participants left with the ‚opinion, that there should be more international seminars in the future!

Matthias Dahlmanns

Matthias is doing his Master studies at the University of Cologne where he is specialising on quantum physics and cosmology. He is also member of NC Germany's board.

PLANCKS 2018 in Zagreb

PLANCKS 2018

Physics League
Across Numerous
Countries for
Kick-ass Students

Zagreb, Croatia

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When? May 11th - May 13th 2018

How? Teams of 3 or 4 undergraduate students solve 10 problems from diverse areas of theoretical physics. They also have fun attending parties, guest lectures and exercises.

Follow us on plancks.org

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international association of physics students

ICPS 2018 in Helsinki

The ICPS of 2018 will be held in Helsinki, the northernmost location for an ICPS ever, except of course for the first ICPS in Helsinki in year 1999. Despite our northern location, summers in Helsinki are (mainly...) warm and sunny. We can almost guarantee you that there won't be any snow!

ICPS 2018 will challenge both the participants and the lecturers to think what their field of science can do to help fight the climate change and other huge challenges we are meeting today. Most of the lectures during ICPS will be held in the historical city centre campus of the University of Helsinki, right in the heart of the city. The campus was built in the early 19th century when the University of Helsinki moved from Turku to Helsinki. It's a beautiful piece of history right in the centre of the busiest part of Helsinki with lots of cafes and shops.

ICPS 2018 will be visiting two other campuses. We will spend one day at Kumpula campus, home of the Faculty of Science at the University of Helsinki.

Kumpula campus is the largest hub of scientific expertise in the Nordic countries. The other campus we will visit is Aalto University's Otaniemi campus. Otaniemi campus is home to the School of Science and Technology and has on-campus living for over 2000 students of science and technology. The campus has also plenty of facilities for free time activities, which we will get to know during the Finnish Night.

Finnish students take student life very seriously. Our student organisations make sure that the students are both happy in their studies and in their free time and they are here to make ICPS 2018 the most amazing experience. You can spot a Finnish student from far away. On student festivities we wear onepiece overalls with different colors, depending on one's major. Another sign of a FInnish student is the special student caps. We have plenty of traditions like academic dinner parties called Sitsit, which you who have attended ICPS before may have seen (or heard) during the Nations Party. We pride ourselves on our huge pub crawls with students from different subjects from all over Finland stuffing themselves in the same bars. You will get a chance to experience these and many more traditions in ICPS 2018. And of course, you can't leave Finland without getting an opportunity to visit a sauna!

Our ICPS 2018 committee has been dreaming many years of organising this fantastic conference and is determined to make this an unforgettable occasion for every one of you. We can't wait to get to say to you:

Tervetuloa Suomeen!

Anton Saressalo
Amalia Ahola

Anton and Amalia from the University of Helsinki are part of the ICPS Organising Committee. Anton is also part of the IAPS EC.

Intermezzo

Bids and Opportunities

ICPS 2019 – Bid by NC Germany

The ICPS is one of the highlights of the year for anyone in IAPS. Therefore, we would greatly appreciate being the host for 2019's conference in Cologne, a city that combines a 2000-year-old history and a very special culture with modern science and economics.

Organising Committee

Our committee consists of enthusiastic IAPS members from all over Germany who want to create their very own ICPS 2019 in Cologne.

The still-growing organising committee consists of 20 active members and we still have good contacts to the organising committee of ICPS 2014 in Heidelberg.

Excursions and Lab Tours

The central location of Cologne within the Rhineland offers access to many research centres and laboratories as well as a bunch of high-tech industries.

The Research Centre Jülich with its more than 1000 scientists is known for their research in various fields of physics, especially energy and environment. Astronomy enthusiasts will be able to visit the radio telescope Effelsberg – with 100 metre diameter the second largest in the world.

Those who prefer to fly to space will like the German Aerospace Center and the Cologne site of the ESA. People interested in high-energy physics will be charmed by ELSA at the University of Bonn. Optics and plasma can be found at the University of Dusseldorf.

These scientific excursions will, as usual, be accompanied by the cultural programme where the range of possibilities is at least as large as for the scientific part.

Scientific programme

In several plenary talks, renowned scientists will speak about life, the universe and (a theory of) everything. In addition to the possibility of presenting your own research, you will have the chance to gain knowledge in crash courses about Quantum Field Theory, Complex Systems and other advanced topics. If you need a more handy stimulus you will have the opportunity to build your own particle detector. Soft skills like how to communicate the results of your research, how to inspire children to do physics, will also be covered.

Nights

The evenings and parties have always been a staple in the ICPS and will continue to be, beginning with the welcome evening and ending with the farewell party. Needless to say, we are going to bring you the traditional Nations' evening as well as the German Evening. You also won't have to miss out on dressing up for the costume party.

Outlook

This conference provides you the possibility to get in touch with up to 500 physics enthusiasts from all over the world to discuss ideas, exchange knowledge and make friends. Where could be a better place to do so, than in a green, diverse and modern city like Cologne?

You want to get more infos about our bid? Then check out our website: www.icps.cologne

Matthias Dahlmanns
Bettina Allner

Bettina is currently finishing her MSc at the University of Halle.

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Part II

Scientific Articles

Studying surfaces and interfaces on an atomic scale: Reviewing the emerging field of spintronics

By revealing the Nobel laureates for Physics in 2016, surface and interface physics were in the spotlight of the scientific community: D. J. Thouless, F. D. M. Haldane and J. M. Kosterlitz were awarded the renowned prize 'for theoretical discoveries of topological phase transitions and topological phases of matter'[1]. They follow in the footsteps of other laureates also having contributed to this field, such as A. Geim and K. Novoselov for the investigation of Graphene in 2010 or A. Fert and P. Grünberg for the discovery of giant magneto-resistance (GMR) in 2007.

Amongst many others, they underline the importance of surface and interface physics in the 21st century. Surface and interface physics deal with properties and interactions of a surface with its surrounding medium. Thin films and hetero-structures have to be treated differently from bulk crystals for many reasons, such as the loss of translational symmetry[2]. Some concepts, like electronic bands, can also be applied, however[2].

Motivation of Research

Surface and interface physics saw a rise in interest over the last decades, since advanced technologies highly rely on its progress. Understanding this field is crucial for addressing various contemporary questions of physics: investigating growing mechanisms of thin films, studying adsorption processes or examining corrosion and surface protection are just some examples[2]. There is a wide range of possible applications, reaching from catalysts over microelectronics to medicines, enhancing industrial processes as well as quality of human lives.

This is why surface and interface physics become more and more important. In fact, if you are reading the digital version of this document, it could be stored in a hard drive disk, whose read-and-write head utilizes a spin-based effect in thin films, namely GMR[3], which will be discussed later. The following chapter will deal with spintronics, a new generation of spin-based electronics, with surface and interface physics playing a major role.

Spintronics

The world of microelectonics is as important as never before: mobile devices, wearable electronics and the 'internet of things' shape our lifestyle. Since the invention of the point-contact transistor at Bell Laboratories, researchers paved the way to enable faster, smaller, and more efficient microelectronics. To reach this, packing more transistors on a smaller area can be considered as crucial for this fast development, which is described by Moore's law: the number of transistors in an integrated circuit shall double each year.

However, physical limits will be reached soon, eventually approximating systems close to the size of an atom. In this regime, coping with quantum mechanical phenomena, the tunnel effect for instance, and of course surface physics pose new challenges for researchers, trying to find solutions for the 'post-Moore era'.

One promising approach is making not only use of the electron's charge, but also of the polarization of its spin. Devices and logics making use of the spin are called *spintronics*, an emerging field of research, which claims to be able to outperform Moore's law in certain areas[5].

Classification

Before discussing one spintronic device in detail, a brief overview shall be given. Low power spintronics can be separated in active and passive devices.

A device is called active, when it relies on both charge and spin degrees of freedom, and passive

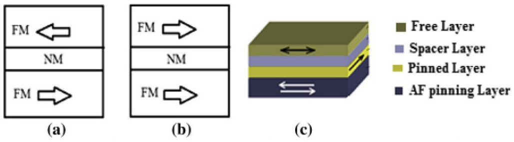

Figure: Illustration of the two possible states of a spin valve (a) antiparallel resistance and (b) parallel resistance[7] (c) Structure of a simple spin valve with four layers[7]

when it only makes use of the spin[6]. Active spintronics are for example spin valves, giant magneto resistances, and magnetic tunnel junctions[7].

Sample device: spin valve

To understand how spin polarization can affect current, the spin valve shall be examined. We consider a sandwich-structure consisting of four layers of materials with different magnetic properties[7] (see Figure).

Starting from the top, the first layer (free layer) is ferromagnetic, whereas the second is non-magnetic (spacer layer) to separate the latter one from the third, a magnetic layer (pinned layer). A fourth layer (antiferromagnetic pinning layer) serves to fix the magnetic orientation of the third one.

Applying a voltage to the stack's layers one and three creates a circuit, taking the tunnel effect for the spacer layer into account. One observes that the resistance is dependent on the alignment of the pinned layer's magnetic field compared to the spin polarization of the electrons, which describes the essence of the GMR effect[8]. For a parallel case, the resistance is low, and vice versa for anti-parallel alignment. Thus, a valve can be constructed, allowing to regulate electron flow through a magnetic field[7].

Applications, potential and impact

After GMR had been discovered in 1988, it took no more than five years to implement this effect in a first application, namely magnetic sensors for the automotive industry[3].

Another application is non-volatile magnetic random access memory (MRAM). Based on magnetic tunnel junctions, these devices were introduced in July 2006 with a storage capacity of 4MB[9]. The development is still ongoing, and future devices have the potential to act as 'universal memory'[9,10]. Apart from that, spin-LEDs enabled measurements of spin injection efficiency, which is a useful tool for spintronic research[4].

Beside inorganic spintronics, organic spintronics will be of interest in future: in general, organic materials bear advantages like high exibility, transparency and low production costs, enabling disruptive new applications, such as printable electronics[7,11]. Progress in this field was demonstrated by the construction of spin-OLEDs.

Outlook

However, organic spintronic devices can not yet be operated at room temperature, which is a hurdle this technology has to take for applicability in everyday use[6]. In the 'post-Moore era', coping with growing demand for data processing power and storage capabilities is as essential as never before. Spintronic devices could be a solution, as they are non-volatile, offer increased data processing speed at decreased power consumption and higher integration densities[5]. Spintronic processing units could enable energy efficient portable devices[7] and boost supercomputing.

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Mario Gaimann

Mario (University of York) won the jIAPS Article Contest 2017.

My mind sticks to the expanding nature of the universe

I am not sure if there exist dark matter or not but I find that it that the, reason of expanding in the units of universe is no mystery called dark matter because science can no way rely on any assumptions for we were not able to find the fact beyond it. Every time I am alone my mind sticks with the fact how can the planets or stars even change their position or get entrapped being in the same regular motion or excite just like an electron but my mind always sees there a vortex motion in everything.

And the mere reason for which the planets are moving away from the center of the sun is nothing else then the decreasing gravity of the sun. Vortex motion must be capable of explaining everything on the universe.

The universe is said to have (just said to have actually there is no any evidence to prove it) extreme inflation within a less than a short period after the creation. Science relying on the assumptions is really ridiculous. It's a fact that the universe is expanding and the expansion has no mystery, if you really call its expansion.

Everything in the universe 'radiates, although the rate of radiation differs from one another. Radiation decreases the mass of the body and increases the size of it. The position between the bodies is highly governed by the gravitational force of attraction between one another.

Newton's famous gravitational equation

$$F = G \cdot \frac{m_1 \cdot m_2}{r^2}$$

As the mass of the bodies' decreases and the size increases the gravitational force of attraction automatically decreases hence the force of attraction between the bodies decreases, which results in the observed expansion of the universe and moving of bodies away from the centre.

Thus, with the bodies expanding and remaining in a motion they follow a Vortex motion. In fact everybody with mass in the universe travels in a vortex motion in its natural state may be clockwise vortex motion or anti-clockwise vortex motion, i.e.. they are towards the origin of vortex on attraction through black hole (annihilation phase of life/body) and they go away from the origin of vortex (creation phase of the body). If we observe this minutely we can observe it in every natural aspects of nature.

We can calculate the exact position and velocity of the body by using the equation of vortex which remains ever changing with time and space. All the heavenly bodies are hence fixed on a complex spirals which is a vortex motions, they emerge with its reach to the extreme point which is the commence of annihilation of it in the black hole using the similar motion. These concepts also satisfy the parallel world theory predicting the presence of existence of many different worlds emergence during the collapse of the black holes. Because the mass of the bodies cannot be destroyed it needs to change into the new worlds eruption. Budding may also occur during the emergence process

Note: Emergence and annihilation is the opposite end of the same point.

Dinesh Ghimire

A whole new world in crystalls

The world physics community had been convinced for ages that crystals only exits in symmetries, according to the restriction theorem[1]. In 1982, Dan Shechtman discovered the impossible, when he observed ten-fold symmetric diffraction patterns[2]. Other physicists did not take him seriously – he was even asked to leave the research group as his professor wanted to prevent being blamed. But as we know by today, Shechtman was absolutely right – what he found was a quasicrystal. This discovery was awarded with the Nobel Prize in Chemistry in 2011.

A similar phenomenon was described mathematically in the early 1970s by Roger Penrose, as he proposed his famous Penrose tiling[3]. Besides the five-fold Penrose tiling, other possibilities to form aperiodic structures exist.

The quasicrystalline state can be understood as a third form of matter in solid state besides crystals and the amorphous state. The atoms are ordered in their positions, but do not show a periodicity. At a closer look, quasicrystals show lots of different electronical, mechanical, and chemical properties.

Examples are an extremely high electric resistivity in aluminium dominated alloys, brittleness at low temperatures and on the same hand extremely deformation at high temperatures, or low wetting of surfaces and hydrogen storage[4], to name just a few.

Quasicrystals have been found in nature, as for example the group of Paul Steinhardt from the Princton University discovered the first natural quasicrystals with composition $Al_{63}Cu_{24}Fe_{13}$ and $Al_{71}Ni_{24}Fe_{13}$ in the Khatyrka meteorite[5]. The main source for quasicrystals is still by synthesis in the lab.

One very special case of quasicrystalline structures are 2D oxidic thin film quasicrystals. In 2013, Förster et al., reported such a structure of the perovskite $BaTiO_3$ on Pt(111) to exhibit a 12-fold symmetry which shows the theoretically predicted Stampfli-Gähler tiling[6,7].

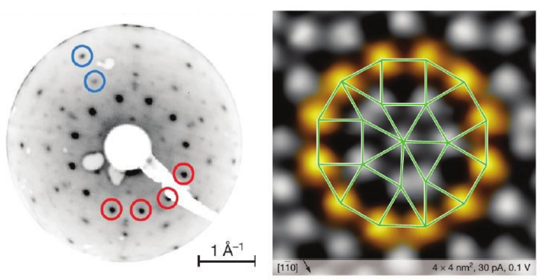

Fig. 1 (LEED) and 2 (STM)

The corresponding LEED and STM images are reproduced in fig. 1 and fig. 2. The STM image shows the characteristic dodecagonal wagon-wheel structure built from two rhombuses, five squares and twelve triangles which cover the substrate.

It was not meant to remain the only quasicrystal to be found. Earlier this year, Schenk et al.[8] reported the discovery of a similar system. Figs. 3 and 4 show the according LEED and STM images. One can clearly see the 12-fold symmetry in the diffraction pattern and recognise the dodecagonal structure in the STM image.

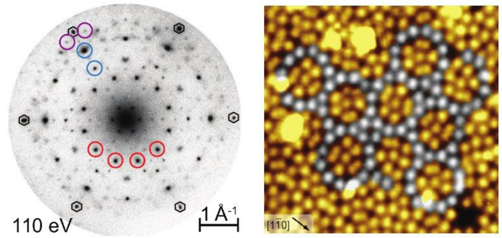

Fig. 1 (LEED) and 2 (STM)

This shows that two-dimensional quasicrystals can form with different lengths on the Pt(111) surface. The understanding of their growth processes and conditions may open a wide field with unexpected and highly interesting properties.

[1] G. Cairns, *The crystallographic restriction, permutations, and goldbach's conjecture*

[2] D. Shechtman, *Metallic Phase with Long-Range Orientational Order and No Translational Symmetry*

[3] M. Gardner, *Penrose Tiles to Trapdoor Ciphers*

[4] H.-R. Trebin, *Quasicrystals: structure and physical properties.*

[5] L. Bindi. *Natural quasicrystal with decagonal symmetry*

[6] P Stampfli. *A dodecagonal quasiperiodic lattice in 2 dimensions*

[7] F Gähler, *Quasicrystalline materials*

[8] S. Schenk, *Observation of a dodecagonal oxide quasicrystal and its complex approximant in the srtio3-pt (111) system.*

Bettina Allner

What do donuts, an insulator and a Nobel Prize have in common?

The answer is Topology. If you paid attention to last year's Nobel Prize in Physics you remember that the prize was awarded to three British physicists 'for theoretical discoveries of topological phase transitions and topological phases of matter'[1]. Topological Insulators are one of these phases of matter.

This special type of insulators appeared when physicists thought materials could all be categorised either as conductors, semiconductors or insulators. However, when Thouless and his colleagues started classifying phases of matter not based on their symmetries and how they were broken, but based on the phase's topological order, everything changed[2].

Imagine an orange and a donut. Although all of them could be a quiz answer to the question 'things you eat', to a mathematician they are extremely different. To them, these pieces of food are characterised by a topological invariant, called the genus – the number of holes in a surface. The situation of insulators vs. exotic insulators is similar to oranges vs. donuts: they are both characterised by topological invariants with different values[3].

The first exotic insulating state to be found was the Quantum Hall State. The effect occurs in 2D materials placed in strong magnetic fields that break time reversal symmetry. When this occurs, the electrons have circular orbits with quantized energy levels, called the Landau Levels.

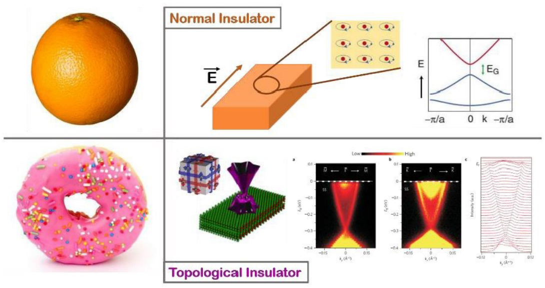

Figure: Orange vs. donut is a similar situation to Normal insulator vs. Topological Insulator state. The surface band structure of a topological insulator has a metallic protected surface state, whereas electrons in a normal insulator do not react to an applied electric field .

Imagine now you want to have an exotic insulator but you do not have a magnetic field. Then, you want a topological insulator. Due to the Spin Orbit Coupling, metallic states in the form of Dirac cones appear on the surfaces of these materials. These states are protected by time reversal symmetry, which basically means that all defects and impurities cannot destroy this exotic state!

As you can imagine, these topological insulators open doors to a multitude of exotic phenomena, like Majorana fermions[3] and a wide variety of applications, from spintronics to quantum computing [4–6]. Let's consider a 3D Topological Insulator. The exotic metallic state appears in the form of an odd number of Dirac cones.

But what are the best topological insulators available nowadays? Only in 2006 the prototype of the 2D Topological Insulator was experimentally realised in the form of HgTe quantum wells[7]. But 3D Topological insulators were still in search.

After some long search in the bottom of the periodic table they found Bi_2Te_3, Bi_2Se_3 and Sb_2Te_3. These newly found topological properties make them some of the most interesting materials for us – physicists.

A lot of excitement exists in the topological insulators community. Who knows what is in store for these fascinating materials? You might just have to stick around and pay attention to them.

[1] Phys. World 29, 1
[2] J. Kosterlitz et al., Int. J. Mod. Phys. B 30, 1
[3] M. Hasan et al., Rev. Mod. Phys. 82, 3045
[4] J. Moore, Nature 464, 194
[5] I. Vobornik et al., Nano Lett. 11, 4079
[6] D. Pesin et al., Nat. Mater. 11, 409
[7] B. Bernevig et al., Science 314, 1757

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