Cheers!
Celebrating the 70th Birthday of Professor Michael Graetzel

Join CN Yang Scholars for an interactive discussion with Nobel Laureate Professor Chen-Ning Yang
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FORTHCOMING EVENTS
3rd International Workshop on Natural and Artificial Photosynthesis in Honour of the 70th Birthday of Prof Michael Graetzel

by Pablo P. Boix Energy Research Institute @ NTU (ERI@N)

Prof Bertil Andersson (NTU President) presenting Prof Graetzel’s birthday gift at the workshop banquet dinner.
The 3rd International Workshop on Natural and Artificial Photosynthesis in honour of the 70th Birthday of Prof Michael Graetzel (Winner of the Millennium Technology Prize, 2010) was held from 11 to 14 June 2014 at the School of Biological Sciences, Nanyang Technological University. This event was jointly organised by the NTU Institute of Advanced Studies (IAS), School of Biological Sciences and Solar Fuels Lab (School of Materials Science & Engineering and Energy Research Institute @ NTU) with sponsorship from the Lee Foundation.

The guest of honour for the event, Prof Bertil Andersson (NTU President) addressed over 24 guests and 200 participants during the opening ceremony.

Many distinguished scientists were present at this special occasion, including Prof Rudolph Marcus (Nobel Laureate in Chemistry, 1992), Prof Daniel Nocera (Harvard, USA), Prof David Cahen (Weizmann Institute, Israel), Prof Mary Archer (Cambridge, UK), Prof Anders Hagfeldt (Uppsala University, Sweden), Prof Nam-Gyu Park (Sungkyunkwan University, South Korea), Prof Can Li (Dalian Institute of Chemical Physics, China), Prof Leslie Dutton (University Pennsylvania, USA), and Prof Fraser Armstrong (Oxford University, UK) amongst others.

This workshop was especially dedicated to celebrate Prof Michael Graetzel’s 70th birthday. The main emphasis was given to his research over the past 40 years in the field of photovoltaics and his distinguished contribution to the development of new photovoltaic systems. During the talks, the speakers also shared their golden memories which they experienced while working with Prof Graetzel. In addition, a wide range of talks was delivered on the development of new generation of photovoltaic...
systems as well as on the possibilities of capturing and converting solar energy into chemical energies stored in the form of hydrogen or liquid hydrocarbons. All the speakers shared the rapid advances in this field in understanding and mimicking natural photosynthesis from different angles: modelling the basic energy transfer processes, developing a deeper understanding of the photosynthesis pathways, to designing artificial photoelectrochemical systems which will help to create technological systems for energy generation using sunlight as the power source.

Prof Rudolph Marcus delivered a talk that covered topics of 'Single Molecule Intermittent Fluorescence Studies of Quantum Dots'. He described the 'Initial Steps in Dye Sensitized Solar cells', and also elaborated on the issues of 'Electron Transfers and Diffusion' that played a critical role in both solar cells as well as in solar fuels. Prof Marcus discussed about the diffusion/electron transfer theory, with special emphasis on 'spectral' diffusion for the quantum dots and particle diffusion for the semiconductor surfaces. Besides the correlations between experimental and theoretical work, the applicability of the electron transfer theory to the field of electrochemistry was discussed with much detail.

Prof Sir John Walker gave a talk on 'New Features of ATP synthases' where he shared the state of the art architectures and mechanistic function of the ATP synthases as well as the ways they are regulated. He elaborated on the link between the features that govern the function of ATP synthases to potential pathways leading to cell death and to human diseases e.g. cardiac ischemia and muscle dystrophy.

Naturally, the highlight of the workshop included the talk delivered by Prof Michael Graetzel on 'Mesoscopic Photosystems for the Solar Generation of Electricity and Fuels'. His talk was focused on the dynamics of heterogeneous photo-driven electron transfer reactions involved in the Dye Sensitized Solar Cells (DSSCs). He also shared his ideas on the molecular engineering and tailoring of the device architecture in order to achieve high efficiency, stability and mass production possibilities. He put light on the recent amazing development of metal halide based perovskite solar cells. The presentation highlighted the journey of dye solar cells in the early 90’s to the perovskite solar cells which have taken the world by storm with efficiencies higher than 18%; the highest in all solution processed solar cells.
The emerging photovoltaic field of perovskite solar cells was the central topic of many exciting talks. Prof Anders Hagfeldt and Prof Nam Gyu Park presented their latest advances in this promising field, with impressive power conversion efficiencies above 16%. Their interesting results along with the optimistic prospects of this technology spiced the discussion sessions after the talks and during the coffee breaks.

The conversion of intermittent solar energy into chemical energy which can be used in demand (and which was named as “personalized energy” by Prof Nocera) was another central topic of discussions during the workshop. Two emerging approaches were identified to engineer photoelectrochemical devices for solar driven water splitting applications. The solar cell-driven electrolyser approach was presented by Prof Daniel Nocera, a pioneer in the field. The audience was impressed not only by the promising solar-to-hydrogen yield of 4.7% achieved, which represents about half of the target defined by the US Department of Energy (DOE) for a viable solar H2 production technology, but also by the fundamental science that elucidated the functioning of the devices.

The so-called Z-scheme tandem photoelectrochemical cell was described by Prof Graetzel himself and other experts like Prof Roel van de Krol, Prof Kazunari Domen, and Prof Can Li. In both the two approaches, electrocatalysis of the hydrogen evolution reaction and water oxidation reaction plays an important role. Prof Licheng Sun and Prof Fraser Armstrong discussed how we could learn from natural systems (PSII and hydrogenases) to design cost effective and efficient alternatives to those relying on precious elements currently used. Prof Per Siegbahn and Prof James Durant’s presentations addressed the mechanisms behind these artificial catalysts functionality within electrocatalytic and photoelectrocatalytic systems.

The workshop concluded with a panel discussion that took a big picture analysis of the development of this field over the past thirty years and what we could look forward to in the years to come. It was clearly acknowledged that solar energy provided the best opportunity for sustainable energy for our planet and considerable inroads have been made in photovoltaics to achieve grid parity. On the other hand, the attendants also left with a clear view that solar fuels continue progressing and provide unparalleled opportunities to address the needs of liquid fuel and also an excellent opportunity for energy storage and carbon dioxide utilisation. The audience had a great opportunity listening and interacting with the international leading figures in their field. The participation of students from all around Asia was materialised in the form of 70 posters presentations, which triggered valuable feedback and discussions with prominent speakers, thus enriching the coffee breaks throughout the duration of the event. Prof Graetzel also presented the best poster awards to the students. Congratulations to the winners!

The three-day workshop culminated in a special banquet at the Raffles Marina Club to celebrate Prof Graetzel’s 70th birthday. A luxurious birthday cake with an aptly worded message summarised the well-wishes of all those in attendance: “In admiration of Michael and many more years to come!”
We had the good fortune to join in an informal interactive discussion with the distinguished professor of Physics who won the Nobel Prize in 1957, Prof Chen-Ning Yang (CN Yang).

The discussion began with Prof Yang’s response to, how he chose his supervisor and the problem to work on at the beginning of his career. His journey began with guidance from his mathematically-trained father, and with some good teachers in his Chinese university, then went for graduate studies in the US. He mentioned that both luck and ability played an important role in his journey. He was a theorist graduate student, so back then, his ability was prized in his group (who are mostly experimentalists, as he wanted originally to do experimental thesis). His supervisor (Edward Teller), whom he was introduced to by Enrico Fermi, managed
to push him towards the theoretical path due to their earlier work together. He wanted to work with the biggest names of the day, but his supervisor who eventually became famous helped him to reach where he is today.

Regarding how one can choose his supervisors, he strongly emphasised the fact that there are two groups of supervisors and students: supervisors who want you to be very independent and exploratory (seen in the American system), or those who would give you much advice and guidance (as in the Chinese system for example). There are two types of students in this field: those who thrive under much guidance, or those who thrive when they are let loose. Which system is best suited depends on your character, interest and inclinations. Both have pros and cons – for example, letting loose may end up losing focus which is essential for in-depth study, while too much guidance narrows your perception and creativity at times.

He stressed the fact that we should strive to find something that interests us instead of simply following what our supervisors are doing. In his opinion, our early education (from primary school till pre-university) should give us some clues about our inclinations even if we may not know the exact thing we want – realising that inclination and pushing towards it is one important step in doing any research or embarking on similar journeys. Doing what interests us most in this sort of work is more important and more likely to end up being worthwhile. At undergraduate level, indeed we probably do not know enough – but knowing your tendencies are often enough to guide you.

This is especially so in this generation, when he was asked about the state of theoretical science today and how science may be different from that in the past. In the past, there were possibilities for graduates to focus very deeply easily in one field of study, but that was also because there were fewer problems to tackle in the past. Now physics as a field of study has become much broader and thinner, and mastering one sub-field is itself much more difficult than it was back then. In a sense, doing theoretical investigations and science in general was “easier” back then when it came to overcoming scope and depth, though choices were not that many. As compared to today, that broadening has resulted in the mastery becoming more difficult to attain, but at the same time it opened up many more doors to investigate: problems are much more abound, and technologies are much better.

Some examples that he gave was the development of hearing aids and MRI. Both were sort of developed in the distant past, but only in recent years were they developed
Prof Yang shared with us his own research experience. Through a series of interesting and thought-provoking stories, we are enlightened by his unique philosophy of research work and life. I was particularly amazed by one story about his refusing to publish a paper because he was not satisfied with the precision of the calculation even though his mentor had encouraged him to publish it. What I learnt from this is to always be prudent on the results so as to maintain a high standard for our work. I believe the success of Prof Yang is partly based on this.

Li Junru
Year 1 CN Yang Scholar from Aerospace Engineering

During the discussion, Prof Yang mentioned the difference between the states of theoretical sciences then and now: Back in his time, technology was not well-developed and thus limiting the choices of problems that scientists could investigate. In our current time, supercomputers and the like give modern theoretical scientists a plethora of directions to venture into. As such, he encouraged us to not be afraid of the prospect of working in the field of theoretical sciences because its range of development, contrary to what most may think, is indeed extremely large. As a student aspiring to be a theoretical physicist, on the one hand, I feel motivated to continue pursuing my dream. On the other hand, I also come to deeply admire the power of pure thought and logical reasoning that has allowed Prof Yang, despite the lack of modern research technology in his days, to come up with brilliant ideas that are still relevant, if not of utmost importance, nowadays in understanding how the world works.

Duong Nghiep Khoan
Year 1 CN Yang Scholar from Physics
with Second Major in Mathematical Sciences

When asked how he goes about identifying important or worthwhile research topic, Prof Yang replied that he thinks all of us sort of know. That is we all know, from young and years of education, what interests us. And he feels, it is by cultivating this interest, that interesting and important discoveries are made. He gave an example of a professor at Beijing University whose childhood interest was to collect stamps. He realised that they are many stamps in the world, and even if he tried collecting all of them, it is unlikely to result in anything worthwhile. Thus he focused his energies on collecting just one type of stamps - stamps about Science. After he retired from his professorship at Beijing University, he published a book with photographs of all the stamps about science that he had collected. This book later won an award and now the professor had moved on to collecting stamps about Mathematics. Prof Yang gave this as an example of how an interest cultivated and developed can result in something valuable.

Ng Chyi Huey
Year 1 CN Yang Scholar from Mechanical Engineering
with Business Minor

Hear what the other CN Yang Scholars said:

01. Scholars See Soo Teck (Year 3, Chemistry and Biological Chemistry) and Li Junru (Year 1, Aerospace Engineering) enjoying the dialogue with the Nobel Laureate.

02. The scholars were mesmerised by Prof CN Yang’s sharing and insights.
Now in its sixth year, the International Science Youth Forum (ISYF) remains an excellent avenue for talented high school students to learn and enhance their interests in science through intellectual dialogues with leading experts in the various scientific fields. The 6th ISYF was held from 19 to 23 January 2014. It was jointly organised by the Institute of Advanced Studies (IAS), NTU and Hwa Chong Institution with strong support from the Agency for Science, Technology and Research (A*STAR) and the Ministry of Education.

We were privileged to play host to eleven eminent scientists: Prof Aaron Ciechanover (Nobel Laureate in Chemistry, 2004), Prof Ada Yonath (Nobel Laureate in Chemistry, 2009), Prof Anthony Leggett (Nobel Laureate in Physics, 2003), Prof David Gross (Nobel Laureate in Physics, 2004), Prof Hartmut Michel (Nobel Laureate in Chemistry, 1988), Prof Jerome Friedman (Nobel Laureate in Physics, 1980), Prof John Robin Warren (Nobel Laureate in Physiology / Medicine, 2005), Prof Kurt Wüthrich (Nobel Laureate in Chemistry, 2002), Prof Martin Chalfie (Nobel Laureate in Chemistry, 2008), Prof Stephen Smale (Fields Medalist, 1966), and Prof Vladimir Voevodsky (Fields Medalist, 2002).

This year’s theme, “Science for Humanity in the 21st Century”, brings into sharper focus our duty to reconcile the potential of Science with the aspirations of human
society as we transit from being curious observers of Science and Nature to becoming burgeoning masters of it. From chemical warfare to bioterrorism, we are constantly reminded of how multifaceted and dynamic scientific research has become. Therefore, this year’s theme aims to bring both society and scientific progress into a common discussion, impressing upon the delegates a deep sense of responsibility and realisation of the complex impact their future scientific work will imprint on the wider community.

Bringing together 90 students from 15 countries and across 4 continents, ISYF aims to provide students with high potential an opportunity to experience Singapore’s world-class research facilities. At A*STAR, participants visited state-of-the-art laboratories, gaining an insight into the lives of researchers, and also first-hand experiences of working with complex laboratory equipment. Delegates also engaged in an inspiring conversation with A*STAR scholars, which helped them obtain an outlook of the potential science scholarships awaiting them.

At NTU, the delegates visited the School of Biological Sciences, School of Physical and Mathematical Sciences, and School of Electrical and Electronic Engineering. The participants were engaged in hands-on activities organised by the facilitators, like visits to the Luminous Lab, trying out ice-cream making, and even various forensic experiments to help solve a murder mystery.

After the Lab visits, the participants engaged in a discussion with a distinguished panel of speakers. They included Nobel Laureates Prof Aaron Ciechanover, Prof Anthony Leggett, Prof Kurt Wüthrich; Fields Medalist Prof Stephen Smale; and Prof Jackie Ying (Executive Director, Institute of Bioengineering and Nanotechnology, A*STAR). Chaired by Prof Bertil Andersson (NTU President), the discussion included moral issues associated with the improvements in science and technology such as the creation of longer life, as well as the pressures that scientists today face together with the motivations that spur them on in their research journeys.

The commencement of Day 4 introduced a new event to ISYF for the very first time. For a couple of hours, delegates set up booths according to their countries in the Inner Plaza of Hwa Chong Institution (College), introducing their cultures to curious College students. The inaugural Cultural Exhibition proved to be a huge success, with an endless stream of students hopping from booth to booth, sampling the delicacies from abroad,
striking conversations with the delegates, and snapping memorable pictures to capture the event.

Another highlight that day was the Nobel Forum. We were honoured to have Prof Wang Gungwu, Chairman of East Asian Institute, Lee Kuan Yew School of Public Policy and the Institute of Southeast Asian Studies, to grace the event. The invigorating discussion spanned across a wide spectrum of subjects – from health to war and space. The crucial takeaway from this diverse discussion, however, was that scientists should not limit their research because of ethical concerns. While it is important to not delve into “bad” science, all types of “good” sciences should be explored. After all, who knows what the future holds, and who knows when our research will come in handy? What is important is that in our application of these good sciences, society upholds and keeps our morality in check. At the same time, the Nobel Laureates also provided words of encouragement for budding researchers, reminding delegates to constantly keep their eyes open, and to not mull obsessively over current ethical issues for now. As Prof Ciechanover summarised pithily, “Don’t ask questions that are 30 000 feet above your head; ask questions which are solvable, so that you can excel and something good will come out of it.”

After 5 days of scientific learning, discovery, and fun, the event was concluded with a Closing Ceremony dinner at Conrad Centennial Hotel. Apart from the scientific skills and competences learned, the most valuable thing ISYF has offered was the opportunity for making connections and forming relationships not only with role model scientists, but also with peers. ISYF has provided delegates the rare chance to interact with likeminded peers from around the globe. They gathered to share their passions for science and education, but connected through so much more: forging new friendships, and for the foreign delegates, exploring a new city and trying new cuisine.

To quote Prof Carl Sagan, “Somewhere, something incredible is waiting to be known.” Indeed, it is sincerely hoped that the delegates would leave the Forum inspired and geared up to pursue their own scientific journeys and leave an indelible mark on humanity and society.
01. Prof Ada Yonath (Nobel Laureate in Chemistry, 2009) with her master class students.
02. Delegates in the midst of solving a murder case study in the School of Biological Sciences, NTU.
03. Hwa Chong students dropping by the Malaysian booth with Canadian flags in hand.
Prof Roy J. Glauber was awarded the Nobel Prize in Physics 2005 for his contribution to the quantum theory of optical coherence. Essentially, Prof Glauber was honoured for jointly creating the field of Quantum Optics. In simple terms, Prof Glauber had developed new calculational techniques in dealing with large numbers of light quanta or photons. Prof Glauber did his undergraduate work at Harvard University and he has played a significant role in the history of World War II. After his sophomore year, he was recruited to work on the Manhattan Project, where (at the age of 18) he was one of the youngest scientists at Los Alamos. His work involved calculating the critical mass for the atomic bomb. After two years at Los Alamos, he returned to Harvard, receiving his bachelor’s degree in 1946 and his PhD in 1949.

Prof Glauber was in Singapore for the Berge Fest conference and the Asian Physics Olympiad (APhO), so Nanyang Technological University’s (NTU), School of Physics and Mathematical Sciences (SPMS) has the honour of inviting Prof Glauber to visit on 9 May 2014 through the arrangement of the Institute of Advanced Studies (IAS). He was first invited to meet the physics faculty and the physics students. As there is a wide range of international faculty and students meeting him, there is a large variety of questions posed to Prof Glauber. The questions include: how he came to like Physics, his experience at Los Alamos and the latest research in quantum optics. At the end of the session, many students and faculty took photos and selfies with Prof Glauber.

Coincidentally, Prince Alfred of Liechtenstein was visiting NTU on the same day. He got to know of Prof Glauber’s visit and requested to meet Prof Glauber.
Prince Alfred had very serious questions regarding nuclear weapons and nuclear power generation as a supposed clean source of energy. He sought Prof Glauber’s opinions especially since Prof Glauber has a vast personal experience in that area. After the meeting with Prince Alfred, we brought Prof Glauber to a Chinese restaurant in NTU, which he enjoyed very much.

After lunch, we travelled back to SPMS where Prof Glauber prepared to give the public lecture “Some Recollections of Los Alamos – and the Nuclear Era” at SPMS LT1. The lecture theatre was packed with undergraduate and graduate students, faculty and members of the public. It was a nontechnical talk where he recalled the days when he was working on the nuclear bomb with his colleagues and the global wartime tensions. He mentioned about how the USA entered into the war resulting in Harvard University accelerating their courses because faculty members were being drafted for the war. That was how he almost completed his graduate school education at the age of 18. Then he spoke about how he was drafted into a war-related project at New Mexico secretly with complicated security clearance. He was on the ride to Santa Fe with John von Neumann, a legendary mathematician. Prof Glauber also showed pictures of the breathtaking scenery of the canyons of the Pajarito Plateau that he saw during his ride. When Prof Glauber was first made known of the intention of the project, he recoiled. He eventually reconciled to the project because of the uncertainty that the Germans had the expertise and thus could be working on a fission bomb as well. He also mentioned the great people who overwhelmed him there were Oppenheimer, Hans Bethe and Richard Feynman. Niels Bohr also occasionally visited Los Alamos whom they address as Nicholas Baker for security reasons. After the war, in early 1946, he resumed his graduate life at Harvard with Julian Schwinger as his thesis advisor after he was so impressed by Julian at a brief encounter at Los Alamos. He then produced a quantum field theoretical thesis in 1949 that laid the foundations to his Nobel prize winning work in 1963.
01. Prof Glauber (with the definition of coherent states behind).
02. Prof Berthold Georg Englert (left) and Ms Atholie Kerner enjoying the lecture.
Berge Fest: Conference in Honour of the 60th Birthday of Prof Berthold-Georg Englert

In celebration of Berge Englert’s contributions to Quantum Information, Quantum Optics, and the Foundations of Quantum Mechanics.

Prof Berthold-Georg Englert has helped the Institute of Advanced Studies organised several successful schools and workshops, for instance, the Les Houches School of Physics in 2009 and the Workshop on Spontaneous Energy Focusing Phenomena and Multiscale Physics under the Julian Schwinger Foundation in 2010.

by Rui Han and Hui Khoon Ng Centre for Quantum Technologies

“...you only have one life to live, so make it mean,” a sound piece of advice Prof Berge Englert would offer to someone seeking guidance in his or her career. As we celebrate Berge’s 60th birthday, it is clear that he is an exemplary follower of his own advice.

The 60th birthday conference for Prof Berge Englert,
Principal Investigator at the Centre for Quantum Technologies (CQT), and Professor at the Physics Department in NUS, was held from 22 to 25 April 2014 in the Ngee Ann Kongsi Auditorium in UTown, NUS. Jointly organised by CQT and the Institute of Advanced Studies (IAS) at NTU, it was attended by about 130 participants, many of whom travelled from all over the world to join Berge in this celebration. The 32 invited talks given by Berge’s colleagues and friends – it is hardly possible to be one and not the other when it comes to Berge – covered a wide range of topics, highlighting Berge’s impact in the many diverse areas of physics over his long scientific career.

Berge began his scientific journey in the University of Tübingen, Germany, where he completed his doctorate degree in Physics in 1981. He then worked as a postdoc under Julian Schwinger in UCLA from 1981 to 1985, and his work from those days on the semiclassical description of the atom formed the core of his habilitation thesis of 1990. He then spent ten fruitful years in the University of Munich, Germany, and subsequently held numerous distinguished visiting professorships at various institutes all over the world. He finally accepted a full professorship position at the National University of Singapore in 2003 and has been in NUS since then, eventually also being one of the founding members of CQT, an NRF Research Centre of Excellence. During his research career, Berge worked on a wide variety of topics, ranging from atomic physics, quantum optics, open quantum systems,
quantum complementarity and wave-particle duality, interferometry, quantum state estimation, quantum many-body physics, and more generally, the foundations of quantum physics. Berge is well-known not just as a brilliant physicist, but also a talented teacher, as evident from the fact that many of his lecture notes from courses he taught are now published and well-used textbooks.

The Berge Fest was a meeting place to discuss recent work in the broad areas of quantum information, quantum optics, and the foundations of quantum mechanics. Nobel Laureate (2012) Prof Serge Haroche presented recent cavity QED experiments in his lab, demonstrating the fantastic ability to control the exact number of photons within the cavity by clever feedback techniques. Prof Gerd Leuchs, from the Max-Planck Institute for Science of Light in Erlangen, Germany, talked about reversing time in optics to get an atom to become a perfect absorber of light. Prof Christian Miniatura, a fellow of IAS and a member of Berge’s group in CQT, discussed further developments in their new discovery of the coherent forward scattering peak in the phenomenon of Anderson localisation. Prof Lev Vaidman from Tel Aviv University in Isreal, a long-time friend and a regular sparring partner for Berge in matters of foundations, described an intriguing interferometric experiment in which light left a trace where it seemingly could not have traversed. These were but a few of the very many memorable presentations at the conference.

One of the most captivating talks of the conference was that by the 2005 Nobel Laureate Roy Glauber. Rather than focusing on his recent research, Prof Glauber chose to tell the audience about his unique experience as a young participant of the Manhattan project. At the age of 18, having already had a solid physics education at Harvard, the brilliant young Glauber was recruited to work at the Los Alamos lab. With many personal stories and photographs taken by his own camera, Prof Glauber transported the audience back to those days of an idyllic and secluded Los Alamos lab in the mountains of New Mexico, the excitement and fervor of the scientific advancement, and the eventual moral struggles of those who contributed towards the project. Prof Glauber, himself turning 89 this year, is probably one of the last surviving members of the atomic bomb project. It was thus a privilege to have had the chance to listen to him share his memories of it.

Another highlight of Berge Fest was the birthday banquet held in honour of Berge Englert. This was at the Raffles Marina Club in Tuas, well attended by Berge’s colleagues and friends. Celebratory speeches by Axel Schenzle, Daniel Greenberger, and Artur Ekert recounted anecdotes about Berge that showed his sharp manner and down-to-earth scientific attitude, always accompanied by a good dose of humour and wit, as a fellow colleague, a teacher, and a friend.

Berge’s 60 years of life thus far has certainly left an indelible mark on everyone around him, as can be clearly seen by the fact that every speaker at the conference pointed out how Berge has inspired their own research work. Here’s then to Berge: Happy 60th birthday, and may there be many more fruitful years to come!
“It was nice to see how a long scientific life connected Berge to the physics community as his friends and colleagues gathered here from all over the globe. Beyond the physical content, quite some impressions will stay with me. More often than once, speakers were referring to Berge’s approach of stating his opinion in scientific matters as ‘fierce’. Having experienced Berge debating ‘on quantum theory’, one might have some idea of what they meant. But maybe Berge himself clarified when he gave the closing talk: As he jumped - with verve and determination - right into a number of misunderstandings he spotted during the conference, the audience could feel how deeply Berge cares about the proper way of how and, perhaps even more importantly, how not to interpret the mathematical formalism of physics. I am certain that his refreshingly direct blackboard presentation will be vividly remembered by all participants for years to come. Besides the scientific contributions, I really appreciated Roy Glauber’s fascinating presentation about his time in the Manhattan project. First-hand experiences of such historic events are hard to come by, and spotting just about every famous physicist of that era on private photographs was certainly a treat. I felt honoured in joining BergeFest and its superb selection of scientists, and I am looking forward to Berge’s 70th.”

Martin-Isbjörn Trappe
Centre for Quantum Technologies

“It was great to see so many of Berge’s colleagues, students, and friends come together in Singapore, to honour Berge and to speak about their latest research. We all enjoyed the nice combination of personal recollections and exciting scientific discussions. The wide range of topics that were presented at the BergeFest was impressive; and it underlined the breadth of Berge’s scientific activities and impact.”

Hans Briegel
Institute for Quantum Optics and Quantum Information & University of Innsbruck
Co-organiser of BergeFest
International Conference and Exhibition on Plague Fighter Dr Wu Lien-Teh jointly organised with the Lee Kong Chian School of Medicine

by Alex Ooi Secretary-General of The Wu Lien-Teh Society

The Minister for Health Mr Gan Kim Yong (third from right), graced the occasion as guest of honour and officiated the opening of the exhibition.
An International Conference and Exhibition on Plague Fighter Dr Wu Lien-Teh was held at the Chui Huay Lim Club on 6 April 2014, jointly organised by the Institute of Advanced Studies and Lee Kong Chian School of Medicine at NTU, the Singapore China Friendship Association and the Dr Wu Lien-Teh Society, Penang.

The event was supported by the Embassy of the People’s Republic of China in Singapore, Tan Kah Kee International Society, Harbin Medical University and Chui Huay Lim Club. A well illustrated and informative photograph exhibition on the life and work of Dr Wu was also on display from 6 to 12 April. The Minister for Health Mr Gan Kim Yong, graced the occasion as guest of honour and officiated the opening of the exhibition. The Ambassador of the People’s Republic of China to the Republic of Singapore, H.E. Duan Jielong, was the VIP guest.

“Heinitiated the formation of the Chinese Medical Association, established the Manchurian Plague Prevention Service and some 20 modern hospitals, laboratories and research institutions, including the Beijing and Harbin Medical Universities. For his “Work on Pneumonic Plague and for identifying the role of the Tarbagan marmot in the disease transmission”, he was nominated for the Nobel Prize in Medicine in 1935. Dr Wu was also recognised as instrumental in the publication of the first medical journal and the establishment of some of the earliest modern hospitals in China. He also established the China Medical Association and was the Director of the National Quarantine Service. The event served to remind us of the fight against possible diseases by developing personal hygiene, a healthy environment and good ethics.

Nine distinguished speakers presented interesting anecdotes covering a wide range of aspects of Dr Wu’s life and work. The local speakers and their topics were:

1. “Learning from SARS” by Dr Lim Suet Wun (Executive Vice President, Parkway Pantai) was the CEO of Tan Tock Seng Hospital during the 2003 SARS outbreak in Singapore. Dr Lim talked about the lessons learnt from managing the SARS experience.
The local speakers were
01. Dr Lim Suet Wun
02. Ms Alison Chong
03. Ms Ong Lay Hong
04. Dr Alex K H Ooi
05. Dr Thirumoorthy
06. Dr Jeevendra Kanagalingam
2. “Wu Family Tree” by Ms Alison Chong (great-grandniece of Dr Wu). She shared with the audience that in 2009, she embarked on the project to locate the descendants of Dr Wu. The project bore fruit in 2013, as she was able to locate 863 descendants.

3. “Making of the Documentary on Dr Wu” by Ms Ong Lay Hong (Executive Producer cum Producer of Documentary “Plague Fighter Dr Wu Lien-Teh”).

4. “Legacy of Dr Wu Lien-Teh” by Dr Alex K H Ooi (Secretary-General of The Wu Lien-Teh Society) who has been promoting his legacy since attending the inauguration of Dr Wu’s dedicated museum in Harbin, Heilongjiang in September 2008.

5. “Public Health Ethics and Ethics in Medicine” by Dr Thirumoorthy (Executive Director, Singapore Medical Association).

6. “Naming of the Dr Wu Lien-Teh House at the Lee Kong Chian School of Medicine” by Dr Jeevendra Kanagalingam (Senior house tutor).

The overseas speakers were:

1. “Re-discovery of Dr Wu’s contributionts to China” by Prof Cheng Guangsheng (Microbiologist, Chinese Academy of Sciences).

2. “Importance of Dr Wu Lien-Teh contribution to China’s Medical Services and Public Health” by Prof Tian Wen-Yuan (Harbin Medical University), and

3. “Born, Bred and Rested” by Mr Clement Liang (Treasurer, Dr Wu Lien-Teh Society, Penang).

A lively discussion followed the talks – discussing how study of Dr Wu’s legacy can impact the future.
In 1948, Weaver wrote the iconic article *Science and Complexity*. In it, he defined complex problems and stated that solving this type of problems would require advanced digital computers – that were not in existence yet – and interdisciplinary teams – that were not yet conceived by science. Weaver alluded to *Hidden Connections* as one of the key characteristics of such complex problems.

In the article, Weaver described three types of problems that were central to the scientific endeavor that started in the 17th century. The first type of problems is characterised by a limited number of variables, the connections between which can ultimately be expressed in one simple formula. The second type is characterised by an immense number of variables or particles (such as gas molecules in a space) that all act independent of each other in unpredictable and erratic ways. However the “whole” has average properties that can be analysed and predicted, using probability theory and statistics. Around

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**3rd Complexity Conference on Hidden Connections**

by Jan Vasbinder Director of Para Limes, NTU

Launch of the Complexity Institute.
the beginning of the 20th century, science made a second
great advance in solving this type of problems.

Solutions to these two types of problems have generated
“game changers” for our world like vaccinations,
antibiotics, cars, television, pesticides, nuclear energy,
plastics, computers, mobile communication and Internet.
But the underlying science generated no insights into the
impact of those technologies on our life or in the
connections and underlying principles that govern
interactions along those connections within and between
natural, social, and human engineered systems.

To find those connections and principles requires a
science that focuses on the third type of problems. Those
are problems in which the number of variables is too
large to reduce their connections to simple formulas, and
that cannot be analysed with the traditional methods of
statistics because the variables show the essential feature
of organisation. This is the category of complex problems.
Most problems in biology, our environments, climate,
economies, cities, and the interactions within our social
and cultural worlds fall within this category. Such
problems form the treasure trove for complexity science,
both because of the challenges to find and understand
the hidden connections, and because of the value of
applying that understanding to the real problems of our
world.

With that in mind, the Complexity Program at NTU
organised its 3rd annual conference: “Hidden Connections”,
with support from the Institute of Advanced Studies.
Hidden Connections was also the perfect theme to celebrate
the launch of the Complexity Institute. It refers to a key
characteristic of complexity science. It connects the ways
of the past with the unknowns of the future. It emphasises
that we are all part of a whole that is totally connected. It
also refers to the hidden connections that created and
support the platform from which the Institute was
launched.

Held at the Nanyang Executive Centre over three days
from 2 to 4 March 2014, the conference was attended by
more than 300 local and overseas participants from
academia, government agencies and industry. Mr Peter
Ho, the guest of honour and a strong supporter of the
complexity program at NTU from the very beginning,
gave the opening speech in which he reflected on the
limitation of reductionist science and the new perspectives
provided by complexity science. Complexity science, or
rather the need to address wicked problems, logically
leads to the need of horizontal collaboration within
governments and between government and population.
In line with that, the Singapore government is now
experimenting with the design approach which puts its
planners and policy-makers into the shoes of the
stakeholders – in the people and private sectors – to gain
better insights into the impact of policies and plans.

Following Mr Ho’s speech, the Complexity Institute was
launched. During a short ceremony some of the hidden connections that lead to the start of the complexity program in July 2011 and to the launch of the Institute, were highlighted.

The conference was then turned over to eleven world class speakers, who, during three days gave insightful and thought-provoking talks and illustrated the relevance and importance of complexity science in every possible field of study, such as technological progress, the big bang, collaboration, culture mixing, synthetic evolution, microbial films and language evolution, to name a few. Each talk was followed by lively and interactive discussions. The eleven speakers were:

1. J. Doyne Farmer (Professor of Mathematics and Co-Director, Complexity Economics, Institute for New Economic Thinking, Oxford Martin School, University of Oxford)

2. Martin Rees (Astronomer Royal and a Fellow [and former Master] of Trinity College, University of Cambridge)

3. Adame Kahane (Partner, Reos)

4. Chiu Chi-Yue (Professor and Director of Research & PhD Program, Nanyang Business School, NTU)

5. Albrecht von Müller (Director, Parmenides Center for the Study of Thinking, Parmenides Foundation)

6. Arieh Warshel (2013 Nobel Laureate in Chemistry and Distinguished Professor of Chemistry, University of Southern California)

7. Ricard Solé (Research Professor, Catalan Institute for Research and Advanced Studies and Head of Complex Systems Lab, Universitat Pompeu Fabra)

8. Staffan Kjelleberg (Director, Singapore Centre on Environmental Life Sciences Engineering)

9. Ricardo Hausmann (Director, Center for International Development and Professor of the Practice of Economic Development, Kennedy School of Government, Harvard University)

10. William S-Y Wang (Professor, Department of Electronic Engineering and Director, Joint Research Centre for Language and Human Complexity, Chinese University of Hong Kong)

11. Brian Uzzi (Professor, Kellog School of Management and Co-Director, Northwestern Institute on Complex Systems, Northwestern University)

Plans for the 4th conference in March 2015, with the theme Emerging Patterns are already underway. It promises to be even better and more exciting than the last. So stay tuned!
This IAS – CERN Novice Workshop on 7 February 2014 gave an introduction to the theory of particle physics, the studies of the elementary constituents of matter and their fundamental forces. The current theory, called The Standard Model, provides an accurate description of all known physical phenomena in the micro-cosmos. Why the lepton and quark patterns look so similar is not well understood. Just like ice cream, the matter particles have different flavors and can mix with one another, leading to some mysterious phenomena such as neutrino oscillations and quark decays.

Speakers and participants of the IAS-CERN Novice Workshop.
All these discoveries, or confirmation of predictions, are impossible without successive developments of particle acceleration and collision machinery. The workshop gave an introductory overview of particle accelerators, and focusing on the current largest – the Large Hadron Collider (LHC) at CERN, Geneva. The talk also stressed on the importance of training the next generation of accelerator scientists and engineers to lead future large-scale accelerator projects at the high-energy frontier.

The primary aim of the workshop was to arouse interest among students in the studies of physics and promote the teaching of physics, in particular, in particle physics in high schools. It exposed teachers and students to the world of cutting edge physics research and experiments showcasing the latest discoveries and advances in these fields. It also introduced them to theories of particle physics, including Standard Model and beyond. It helped to stimulate activities related to the popularisation of physics within and beyond the classroom and introduced the audience to the Particle Accelerator and the Particle Detector System.

Distinguished speakers like, Prof Ignatios Antoniadis (CERN) and Prof Emmanuel Tsesmelis (CERN & University of Oxford), provided in their lectures, introductions into the theory of particle physics and to particle accelerators, respectively. As Prof Zhi-zhong Xing (Institute of High Energy Physics, Chinese Academy of Sciences) delved into the mysterious flavors of particles and forces in the Standard Model, Prof Harald Fritzsch (Ludwig-Maximilians University Munich, Germany) helped connect the particle physics theories to the Big Bang. Building on that connection Prof Albert De Roeck (CERN), updated us on the ‘news from the Large Hadron Collider – the Big Bang machine’. As with all scientists, questions remain to be explored and Prof Ngee-Pong Chang (City College of New York & IAS, NTU) explored the complexities associated with the rich family of Higgs Bosons, questioning, ‘What if the Higgs has brothers..?’

The attendance for the workshop included about 300 high school students from Junior Colleges and High Schools as well as Polytechnics and International Schools. The keen interest and enthusiasm of the students was much appreciated by the invited speakers who took the time to answer their queries and interact with them over the tea and lunch break.

The feedback from the students was especially encouraging as they felt the workshop introduced them to a new topic in quantum physics and gave them insights into the current experimentation and advancements in the realm of quantum mechanics and research carried out at CERN and the LHC’s. With another fruitful and fulfilling experience, students and teachers are now looking forward to next years’ IAS-CERN workshop.
The talk was enriching as it made us realise how discoveries of new particles and theories of quantum physics allows us to trace back the events from the evolution of the universe.

Tiffany
River Valley High School

The IAS – CERN Novice Workshop was inspiring and an eye opener to the world of particle physics. As an introduction to particle physics it was simple enough and understandable but at the same time the content was rich and covered many topics related to particle physics, such as its dark matter and antimatter, the Standard model and theories outside the Standard Model like the String Theory. It was interesting to learn about this other field of physics outside the textbook and it has piqued my interest in the other fields of physics that I have yet to learn.

Thank you for the enjoyable, inspiring and informative workshop that introduced me to the relatively new field of particle physics.

Joy Khoo

I think I quite enjoyed the workshop, as did most of the students. Some parts of the talks may have been a bit technical but fruitful.

Dave Lommen
Teacher, Hwa Chong Institution

The workshop was very interesting, very informative and very well organised. A workshop aiming at a wide audience is not easy but this conference managed to do so. In particular the lectures were of great quality with very good speakers. I certainly enjoyed being part of this event which will inspire me for my career as a physicist.

Christophe Couteau
Associate Professor,
NTU-CINTRA & UTT France
International Conference on Flavor Physics and Mass Generation Conference

by Harald Fritzsch Ludwig-Maximilians University Munich, Germany

The International conference on “Flavor Physics and Mass Generation” was held at the Nanyang Technological University (NTU) from 10 to 14 February 2014. This conference followed the inaugural conference on “Flavor Physics in the Large Hadron Collider (LHC) Era”, held at NTU in November 2010. There were 61 distinguished speakers and 60 participants registered for this conference.

The start of the LHC at CERN is bringing particle physics to a new energy frontier, at which fundamental questions associated with the Standard Model were answered and new physics observed.

A basic question was how the masses of the particles were generated and whether these masses can be calculated. The strong interactions were described by
Quantum-Chromodynamics (QCD), a gauge theory of quarks, interacting with the gluons. The hadrons, e.g. the proton, are bound states of quarks – the proton consists of three quarks. The masses of the hadrons can be calculated in QCD.

However the masses of the weak bosons or of the leptons and quarks cannot be calculated. In the Standard Model they were generated by the “Higgs” – mechanism, named after Peter Higgs, who proposed this mechanism in 1964 and was awarded the Nobel Prize in Physics in 2013 for the discovery of the Higgs Boson.

This mechanism requires that there should exist a scalar boson, the “Higgs” boson. The strengths of the coupling of this boson to the weak bosons and to the leptons and quarks determine their masses. If this mechanism was correct, there was no possibility to calculate the masses of the weak bosons, since they were functions of the vacuum expectation value of the scalar field, which is unknown.

Thus in the Standard Model, there were two different ways to generate masses. The masses of the hadrons were generated dynamically by the interaction of the quarks and gluons and can be calculated; while the masses of the weak bosons were generated by the Higgs–mechanism and cannot be calculated. In 2013 a new boson with a mass of 126 GeV was discovered. Thus far it is not known, if this boson is the Higgs-boson.

The implications of this discovery for the physics of quark and lepton flavors were discussed at the conference. A. De Roeck gave a lecture on the experimental results obtained at the LHC. W. Hollik and T. Becher discussed the various mechanisms for the production of the Higgs boson at the LHC. E. Ma discussed the possible connection of the Higgs boson with the dark matter in the universe.

Fritzsch suggested that the new boson was not the Higgs boson, but an excitation of the Z-boson. In this case the weak bosons cannot be elementary gauge bosons – they were bound states as the rho-mesons in QCD. In this theory there is also a new stable bound state, which can form the dark matter in the universe, as discussed subsequently by J. Sola.

An overview of the various aspects of flavor physics was
given by G. Martinelli. The new experimental results were described in the talks of F. Palombo, M. Pepe-Altarelli, M. Kweon and M. Yamauchi.

G. Altarelli and M. Schmidt discussed the various theories to describe the neutrino masses and the flavor mixing of the leptons. The talks of C. Jarlskog and S. Petcov focused on various aspects of CP-Violation. Z. Xing described the possibility to determine the Majorana phases by neutrino-antineutrino oscillations. Neutrinos and the dark matter in the universe were the topics of the talks by M. Lindner and J. Kubo.

The flavor mixing angles of the quarks and leptons are presumably related to the masses of the quarks and leptons. They can be calculated, if the mass matrices of the fermions have “texture zeros”, as described by G. Ahuja, A. Bhatti, M. Gupta and T. Mannel. The connection to “Grand Unification” was discussed by M. Spinrath.

The observed mass hierarchies can be a sign towards the new physics beyond the Standard Model, as discussed by I. Antoniadis. The new physics was also the topic of the talks by M. Beneke, N. Chang, R. Fleischer, G. Hou, A. Manohar, M. Neubert and R. Sinha.

One session was devoted to the physics of the strong interactions. The calculation of the masses of the hadrons in QCD was described by P. Minkowski and W. Plessas. J. Bluemlein discussed the violations of the scaling behaviour in deep inelastic scattering, and R. Crewther the role of the chiral symmetry in QCD. The confinement of the quarks and gluons was the topic of the talk by S. Brodsky.
Colloquia by IAS Visiting Professor
Prof Leon Chua (Berkeley): “Everything you want to know about Memristors but are afraid to ask!”

by Neelakantan Narasimman
VIRTUS, IC Design Centre of Excellence, NTU

Prof Chua is a professor in Electrical Engineering & Computer department at University of California, Berkeley. He is also the inventor of Chua’s circuit and was the first to conceive the theories behind, and postulate the existence of the Memristor. Prof Chua visited IAS from 25 to 28 May 2014. In relation to his visit, he gave a talk on Memristors on 26 May 2014 at the School of Electrical and Electronic Engineering. Memristors were proposed in 1971, via an axiomatic circuit-theoretic approach, as an element having non-linear relation between electric flux and electric charge and was dubbed as the “Fourth Circuit Element”. Hewlett Packard reportedly made the first working nanodevice in April 2008 thereby opening the possibilities of the new circuit element.

Memristors are a class of resistors defined by state dependant ohms law. Different resistance values depending on the state enable it to be used as a data storage element. The resistance value thus obtained in a state does not change when power supply is turned off making it a non-volatile memory. Memristors cannot store energy unlike a capacitor/inductor. Memristors could be found in many unrelated disciplines ranging from brain science to botany. Memristors in any discipline could be identified with signatures for non-periodic waveforms and fingerprint for periodic waveforms.
phase relationship between voltage and current at zero crossing for any non-periodic input waveform, forms the signature. The pinched hysteresis loop for a periodic waveform forms the fingerprint. For a DC supply connected across Memristor, the electric flux builds up, thereby increasing the conductance of Memristor and damaging it eventually.

Even if a first nano device Memristor was made in 2008, Memristors could be dated back to 1801 in Sir Humphrey Davys Electric Lamp. Prof Chua discussed further the varied range of applications of Memristors. Memristors could be used as a non-volatile memory RRAM, and is scalable up to one atom size. It could be used as a logic gate to implement two input boolean functions. Two Memristors can be used to implement material implication logic, which alone would be able to generate any other Boolean function. A typical Full adder could be built using ten Memristors as material implication logic gate, while it needs 50 transistors in CMOS technology. Two Memristors with PTAT and NTAT characteristic can be used to build oscillators. One other exciting application of Memristor is the use as a learning element in circuits. On providing an action potential, circuit with Memristor could be trained to get a specific response. Prof Chua demonstrated the learning capabilities of a Memristor by sharing the results of experiments analogical to the ones conducted in amoebas, snails, dogs, squids etc in search of memory and intelligence by Nobel Laureates. These characteristics make Memristors a good fit in artificial neural networks, machine learning circuits and brain computers. With wide range of characteristics that fit in variety of applications, Memristors are definitely going to be an integral part of electronic circuits in the future. Prof Chua ended the talk on a lighter note saying the idea of Memristors outlived 37 years of opposition to prove its worth. The talk was followed by series of questions from the audience about leakage, environment effect, and ideal/extended Memristors and so on. More than 250 students, researchers, industry engineers and faculty members attended the talk.
Colloquia by IAS Visiting Professor

Prof Leon Chua (Berkeley): “The Origin of Complexity: Local Activity and the Third law of Thermodynamics”

by Huynh Hoai Nguyen Complexity Institute, NTU

“The twenty-first century will be the century of Complexity”, said physicist Stephen Hawking in an interview at the end of last century. A new field of research has emerged since the latter half of twentieth century and rapidly become blossom within the last two decades thanks to the availability of a new and powerful generation of computers that allows massive computational studies to be carried out. Many research centres have been established at different places all over the world, an enormous number of scientific journals have been born and countless conferences have been held to facilitate communication between researchers in this fast-growing field. As time goes by, more and more fascinating studies are conducted, yet there is still lacking a very fundamental and rigorous understanding in the field: What is Complexity? Prof Leon Chua from the University of California, Berkeley provided some insights into this active and exciting field of research at the School of Physical and Mathematical Sciences on 27 May 2014.

It is known from the second law of thermodynamics that no structures or patterns can exist in any closed system, and hence, it predicts a boring lifeless and featureless scenario for isolated closed systems. Yet, in nature we can find abundant examples of non-homogeneous spatial and temporal patterns, for example, cloud shape, terrain, earthquake’s statistics or animal skin patterns. These examples and related phenomena have since then been actively discussed under a wide topic nowadays known as “Complexity”. On the other hand, in thermodynamics, while the first and second laws well describe the behaviour of different physical systems, the third law does not go in line with this nor does it have any practical application. Indeed, many physicists have been long searching for a missing new physical principle that could explain Life or behaviour of living organisms, which takes place under conditions contrary to the applicable domain of second law of thermodynamics. Therefore, there is fundamental need for a new law that could be of complement to the second law and also its equivalent counterpart for open systems.

In the search for this principle, in his work, Prof Chua introduced the concept of local activity which originates from his own studies in electronic circuits. With this concept, he arrived at the local activity principle, which asserts that the correct physical variable whose amplification is essential for complexity to emerge is energy.
This principle in fact provides an important complement to what have been known in the literature as the necessary conditions for complexity, i.e. input of energy, presence of nonlinearity and amplification of fluctuations. By a mathematically rigorous proof, Prof Chua could show that Complexity and Emergence phenomena are impossible without local activity. This principle of local activity is, therefore, precisely the answer to Boltzmann’s search for a missing principle for life against the struggle for entropy, as well as Schrödinger’s hypothetical negative entropy or Prigogine’s quest for an instability of the homogeneous principle; all of which were posed by the great physicists many decades ago.

According to Prof Chua, a system could be either locally active or passive. The locally passive regime is where the second law of thermodynamics applies whereas the new law is applicable to the locally active regime. In the active regime, there is a small but interesting region called the “edge of chaos” in which the systems can generate patterns and exhibit complexity. And in the regime, local passivity implies no complexity. In other words, one can say that the second law of thermodynamics sentenced us to death and this new law of thermodynamics gives us life. Prof Chua’s theory, despite its involvement of difficult mathematical proof, would require no more than basic knowledge in ordinary differential equations and linear algebra to be able to apply it. He showed that using a system described by simple set of ordinary differential equations, many examples of pattern formation in nature could be reproduced and explained.

Prof Leon Chua has published a number of articles and books on the subject of Complexity including Local Activity Principle: The Cause of Complexity and Symmetry Breaking (Imperial College Press, 2013, with Klaus Mainzer), The Universe as Automaton: From Simplicity and Symmetry to Complexity (Springer, 2011, with Klaus Mainzer) and A Nonlinear Dynamics Perspective of Wolfram’s New Kind of Science (World Scientific, 2007).
In superstring theory and in supergravity theories, the U duality is a different kind of symmetry from the standard ones used in particle physics. In the case of N=8 supergravity, this symmetry is the exceptional group E_{7(7)} and it plays a remarkable rôle which is still not fully understood. There are indications that even larger exceptional symmetries could be fundamental in our understanding of the fundamental theories. The exceptional symmetries are also connected in a significant way to the spacetime symmetries. In this workshop, these issues will be penetrated and discussed by some of the leaders in this field.
FORTHCOMING EVENTS

5 to 7 November 2014
28th General Assembly of the International Union of Pure and Applied Physics (IUPAP)
Nanyang Executive Centre, NTU

10 to 12 November 2014
International Workshop on Exceptional Symmetry and Emerging Spacetime
Nanyang Executive Centre, NTU

2 to 5 December 2014
Quantum Effects in Biological System Workshop 2014
School of Physical and Mathematical Sciences, NTU

18 to 22 January 2015
7th International Science Youth Forum with Nobel Laureates in Singapore
Hwa Chong Institution

18 to 23 January 2015
3rd Global Young Scientists Summit
NTU (Main organiser: National Research Foundation)

26 to 28 January 2015
International Workshop on Polyelectrolytes in Chemistry, Biology and Technology
Nanyang Executive Centre, NTU

4 to 6 February 2015
IAS-CERN Workshop on Particle Physics and Cosmology
Nanyang Executive Centre, NTU

9 to 12 February 2015
International Conference on Neutrino Physics
Nanyang Executive Centre, NTU

April 2015
2nd Singapore Sustainability Symposium
Jointly with Sustainable Earth Office

Institute of Advanced Studies
Nanyang Executive Centre
60 Nanyang View #02-18
Singapore 639673
Tel: (65) 6790 6491
Fax: (65) 6794 4941
Website: http://www.ntu.edu.sg/ias

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