Celebrating the 90th Birthdays of Professor Freeman Dyson & Professor Rudolph Marcus
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Conference in Honour of the 90th Birthday of Freeman Dyson

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FORTHCOMING EVENTS
The Conference in Honour of the 90th Birthday of Rudolph Marcus was held at the Nanyang Executive Centre from 22 to 24 July 2013. It was organised by the Institute of Advanced Studies (IAS) at the Nanyang Technological University (NTU) with sponsorship from the Lee Foundation. The presence of many international participants amongst the locals added much diversity to the special occasion.

Prof Marcus’s groundbreaking theory on electron transfer won him the Nobel Prize in Chemistry in 1992. Named after him, the Marcus theory provides a thermodynamic and kinetic framework for describing electron transfer reactions in chemical and electrochemical systems as well as in biology. The understanding of the basic energy converting processes in photosynthesis has influenced the development of technologies such as solar cells and batteries. The Marcus theory has since become the dominant theory describing electron transfer reactions that are ubiquitous in chemistry and biology.

Prof Bertil Andersson (NTU President), graced the opening ceremony as Guest-of-Honour. Among the 19 international speakers were Nobel Laureate Prof Yuan Tseh Lee and Millennium Technology Prize Laureate Prof Michael Graetzel. They were appointed as the Lee Kong Chian Distinguished Professors in relation to their visits to Singapore. Other luminary speakers included Professors Harry Gray (Caltech), Wolfgang Junge (University of Osnabrueck), Nathan Lewis (Caltech), Mark Ratner (Northwestern University), Dongping Zhong (Ohio State University) and many more.

As a tribute to Prof Marcus’s lifelong contributions to
chemistry, the speakers delivered a wide range of talks on present-day research and its projections into the future. The engaging topics included Perspectives in Energy Conversion, New Developments in Biological Physical Chemistry at the Molecular Level, and Recent Developments in Theory.

Prof Michael Graetzel, the Swiss pioneer of “artificial photosynthesis”, gave a presentation on “Dynamics of heterogeneous electron transfer reactions in mesoscopic solar energy conversion systems”. He greatly elaborated the dynamics of heterogeneous photo-driven electron transfer reactions and how they play a vital role in mesoscopic solar energy conversion systems. Mastering light energy harvesting and the rate of charge carrier generation, recombination and collection is the key to realising efficient solar energy conversion. Recent progress in the molecular design of donor-acceptor sensitiser, the discovery of perovskite pigments as light harvester, and the replacement of electrolytes by solid charge transport materials had resulted in an impressive improvement in photovoltaic performance. The low cost and ease of production of the new cell will certainly benefit large-scale applications.

Entitled “Elementary Processes Involved in Matrix Assisted Laser Desorption Ionisation of Biological molecules”, Prof Yuan Tseh Lee’s lecture discussed the recent investigations and new understanding of elementary processes involved in Matrix Assisted Laser Desorption Ionisation (MALDI). Many important energetic molecular ionic processes were derived from the precise controls of excitation energies of parent cluster ions. The understanding of the change in the photochemical processes by molecular associations or proton-transfers is of fundamental importance in the understanding of MALDI.

Separately, Prof Dongping Zhong delivered an interesting talk on “Electron transfer in DNA repair”. He described how DNA damage caused by ultraviolet irradiation, which could lead to serious problems such as genome mutation and potential skin cancer, can be restored completely by photolyase enzymes in nature with blue light. In a nod to the theory developed by Prof Marcus, he added that the electron-transfer dynamics follow the Marcus theory with a novel electron tunnelling pathway.

All in all, the talks were truly incisive and insightful. The audience had a wonderful opportunity listening and interacting with the international leading figures in the field. The three-day conference culminated in a special banquet at the Tanglin Club to celebrate Prof Marcus’s 90th birthday. A luxurious birthday cake with an aptly-worded message summarised the well-wishes of all those in attendance: “In admiration of Rudy and many more years to come!”
It was wonderful to see Prof Marcus again at NTU during the conference honouring his 90th birthday. The last time we got together, it was over 10 years ago at the Fall Convocation at the University of Waterloo. I had nominated him for an Honorary Doctorate of Science. As Prof Mark Ratner pointed out in his talk, Rudy is almost invariant to the time evolution operator; he looked just the same as he did ten years ago. And as always, Rudy never failed to make acute comments and observations throughout the sessions. This was a well-organised conference, with many high calibre talks. The organising committee must be congratulated for doing such a superb job. I was glad to see many old friends as well as make new acquaintances. This was a conference that left a lasting impression on me.

Wing-Ki Liu  
Department of Physics and Astronomy, University of Waterloo

It was a great experience to attend the conference and to see Prof Rudy Marcus in person. His theory in electron transfer is very important in many fields. At the conference, I had the opportunity to listen to many good research presentations, and realised how these fields of research have grown since the introduction of the Marcus theory. It is also impressive that Prof Marcus is still an active professor at the age of 90. It was a good conference to celebrate his 90th birthday with many excellent talks.

Kazuteru Nonomura  
Energy Research Institute @ NTU

The three-day conference held at NTU was good and beneficial to NTU academics and students. There was much to learn from the speakers.

Poh Hee Kim  
Office of Academic Services, NTU
In an episode of the popular science fiction series *Star Trek: The Next Generation*, the crew of the USS Enterprise-D happened upon a full Dyson sphere when its gravitational fluctuations brought them to a stop. After some analysis of the sphere, Lieutenant Commander Data informed that the inside surface area of the sphere was equal to “250 million class-M worlds”.

Given the gravity and seriousness of the situation, one might actually believe that Dyson spheres exist, were it not for the fact that the *Star Trek* series is merely a work of fiction. In reality, a Dyson sphere is a hypothetical megastructure where a “sphere” is a system of orbiting solar-power satellites meant to completely encompass a star and capture most or all of its energy output. Named after its creator, the concept of the Dyson sphere is just one of the many diverse contributions Prof Freeman Dyson has given to humanity.

To celebrate his illustrious career in physics, mathematics, astronomy, nuclear engineering and climate change, the Conference in Honour of the 90th Birthday of Freeman Dyson was held from 26 to 29 August 2013 at the Nanyang Executive Centre. The event was organised by the Institute of Advanced Studies (IAS) at the Nanyang Technological University (NTU), with the support of Lee Foundation. The Guest-of-Honour for the event, Prof Bertil Andersson (NTU President), addressed over 160 speakers and participants who came from different parts of the world to join in the festivities.

Many renowned scientists were present at the special occasion, including Prof David Gross (Nobel Laureate in Physics, 2004), Prof Cecile DeWitt (University of Texas, Austin), Prof Shou-Cheng Zhang (Stanford University and Tsinghua University), Prof Xiao-Gang Wen (Perimeter Institute and MIT), Prof Kazuo Fujikawa (RIKEN), Prof
Molin Ge (Nankai University), Prof Yue-Liang Wu (University of Chinese Academy of Sciences), Prof Zhong-Can Ouyang (Institute of Theoretical Physics, Chinese Academy of Sciences), Prof Lawrence Krauss (Arizona State University and Australia National University), Prof Phillip Schewe (University of Maryland) and many others. In relation to their visits to Singapore, Prof Freeman Dyson and Prof David Gross were appointed as Lee Kong Chian Distinguished Professors.

A wide range of topics was discussed at the conference, including High Energy Physics, Condensed Matter, Quantum Physics and Statistical Physics.

In Prof David Gross’s talk on “Quantum Field Theory: Past, Present and Future”, he traced the development of quantum field theory from the early days of field theory formulated by Faraday, Maxwell and Einstein to the recent development of string and brane theory, where it was found that the low energy mode of string ends on different branes forming gauge theory. Prof Gross also mentioned that like string theory, quantum field theory is not really a theory. Rather, it is a framework that probably captures in a fundamental way the properties of space-time — removing the necessity for smooth manifold, fixed topology and fixed dimensions.

Another talk that drew much interest was delivered by Prof Shou-Cheng Zhang. Entitled “Topological insulators and superconductors”, he gave a report on the recent theoretical and experimental prediction of a new class of topological states. Topological insulators have an insulating gap in the bulk, but have topologically protected surface states due to the time reversal symmetry. He reviewed recent theoretical and experimental progress, and a number of outstanding issues in his field of research. The areas he discussed include the quantised anomalous Hall Effect, quantised magneto-electric effect, the topological Mott insulators and the search for topological superconductors. The sharing of ideas and viewpoints by Prof Zhang generated a great amount of excitement and interest among the participants in the field of topological insulators and superconductors.

Overall, the engaging talks by all the eminent speakers brought about greater insights and invoked deep thinking among many of the participants.

Public Lectures by Prof Lawrence Krauss and Prof Phillip Schewe

Another highlight of the conference was the public lectures that were delivered by two popular American scientists, Professors Lawrence Krauss and Phillip Schewe. The public lectures were held on 27 August 2013 at Hwa Chong Institution. Although it fell on a weekday, the lectures attracted overwhelming attendance of more than 400 enthusiastic participants.

Prof Lawrence Krauss is a renowned cosmologist and
01. Prof Xiao-Gang Wen engaging in a discussion with NTU students during the coffee break. | 02. (From left) Prof Shou-Cheng Zhang, Prof Yue-Liang Wu, Prof Dyson and Prof Molin Ge posed for a memorable photo after the lecture. | 03. Prof Zhong-Can Ouyang and Prof Yue-Liang Wu presenting an exquisite birthday gift to Prof Dyson. | 04. Prof Cecile DeWitt (left) reminiscing over a photograph with Mrs Dyson and Prof Dyson. | 05. Prof Lawrence Krauss (left) and Prof David Gross were portraits of happiness at the joyous occasion. | 06. Prof Lawrence Krauss delivered his talk to a packed audience at the public lecture.
science populariser. He is the Foundation Professor of the School of Earth and Space Exploration as well as the Director of Arizona State University’s Origins Project. Other than being a scientist, he is the author of several bestselling books, including *The Physics of Star Trek* and *A Universe from Nothing*. Prof Krauss gave a very captivating lecture entitled “The Greatest Story Ever Told... So Far”. In his talk, he presented a fascinating scientific story based on the Standard Model, a theory that was developed by the collective efforts of many scientists. The journey brought the audience from Plato to Einstein, to Feynman and Dyson, and beyond, to the discovery of the Higgs Boson. He also discussed the implications of the discoveries relating to the Standard Model on our fundamental understanding of space and time, and how it helped to possibly shed some light on the formation of the universe and its future.

Prof Phillip Schewe, who has the honour of publishing the only full biography of Prof Dyson, titled *Maverick Genius: The Pioneering Odyssey of Freeman Dyson*, gave a talk on “Science and Sublime: The Life of Freeman Dyson”. He is the Director of Communication at the Joint Quantum Institute, University of Maryland and the chief science writer at the American Institute of Physics. Prof Schewe gave the audience a detailed and thorough review of Prof Dyson’s illustrious life. The presentation not only gave the audience a detailed account of Prof Dyson’s varied career, but also a glimpse into his personal life.

Still sharp-witted as ever, Prof Dyson’s tireless pursuit for knowledge is an exemplary quality that inspired many who attended the conference.

The Conference in Honour of 90th Birthday of Freeman Dyson was a wonderful knowledge sharing platform for students of different schools to meet worldwide top leading scientists. NTU students had the opportunity to meet speakers who had years of expertise in their fields of study. This conference was a real-eye-opener for me as it exposed me to the fascinating world of quantum physics, which was a topic not usually learned by engineering students. I am more interested in exploring the quantum view of physics after attending this conference. A wide variety of topics were delivered and conducted in a place with state-of-the-art facilities, which enhances the learning process. The conference was well-planned and far exceeded my expectations. I hope to attend more of such events by IAS.

Kenneth Kam Keen Chong
School of Mechanical and Aerospace Engineering, NTU

It was a great honour to meet Prof Dyson and so many renowned physicists at the conference. Having joined other brave scientists in establishing profound and revolutionary theories since the 1950s, Prof Dyson surely represents one of the greatest minds of the older generation in physics and beyond. As the younger generation of physicists, I felt both great excitement and pressure in taking up the baton from the older generation after listening to their encouraging and enlightening talks. I feel very inspired by this conference, and I hope IAS can organise more of such events in the future.

Su Lei
School of Physical and Mathematical Sciences, NTU
Interactive Session with Nobel Laureate Prof David Gross

Looking forward to the future of physics research

by David Kum Wei Kuan NUS High School of Mathematics and Science

On 27 August 2013, the NUS High School of Mathematics and Science had the honour of hosting an interactive session with Prof David Gross (Nobel Laureate in Physics, 2004). The event was coordinated by the Institute of Advanced Studies and the Science Centre Singapore in relation to the “Sketches of Science” exhibition of Nobel Laureates. Prof Gross is one of the theorists working on the asymptotic freedom in theory of the strong interaction back in 1973 along with Prof Frank Wilczek and Prof David Poltzer. He was awarded the Nobel Prize for this work in this area, along with many other notable achievements such as the Dirac Medal in 1988.

Prof Gross’s lecture was well received by the students. The talk covered the background of quantum physics, providing rich and substantial insights to the budding scientists of NUS High who were looking to start their explorations in the field of the quantum world. After a quick run-through of the history, Prof Gross updated the students on the latest news in the field of particle physics, highlighting especially the discovery of the Higgs boson which created much excitement throughout the international scientific community.

Prof Gross also highlighted the characteristics students should strive to attain so as to become good researchers. Being constantly curious, having the ability to aim high and fall hard, and a genuine passion and love for physics were some of the points he mentioned. The talk went a long way in encouraging the young generation of scientists to take up research and help demystify the wonders of science.

Personally, this was a very interesting experience for me and my friends who are very keen in quantum physics. We relished the chance to interact with such a prominent physicist who is an expert in his field. Prof Gross was an engaging speaker and explained the concepts in layman terms so that everyone could understand. He ended off with the note that there are still more mysteries and unexplained phenomenon that could be explored in the field of quantum chromodynamics and string theory; it really made many of us look forward to the future of physics research.

Following the talk, we had a good discussion on the life ahead of us as physics students and it was very helpful in preparing ourselves for the future. As Prof Gross put it reflectively, we are the next generation that will lead the physics field in formulating theories and conducting research in the future, building upon the achievements of Prof Gross’s generation to further our knowledge of the universe, just as he once built his research on the shoulders of his own professors.

Thanks Prof Gross for the words of wisdom!
The students were enthused by Prof Gross’s lively and engaging talk. Many students crowd around Prof Gross after the talk to seek advice from the Nobel Laureate.
Now in its fifth year, the International Science Youth Forum (ISYF) is still a great avenue for talented high school students to learn and enhance their interests of science through intellectual dialogues with leading experts in the fields. The 5th ISYF was jointly organised by Institute of Advanced Studies (IAS) 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 five eminent scientists: Prof Sydney Brenner (Nobel Laureate in Physiology or Medicine, 2002), Prof Albert Fert (Nobel Laureate in Physics, 2007), Prof Douglas Osheroff (Nobel Laureate in Physics, 1996), Prof Danny Shechtman (Nobel Laureate in Chemistry, 2011) and Prof Vladimir Voevodsky (Fields Medalist, 2002).

This year’s theme “Breaking Through” highlights two important aspects of the scientific journey. Firstly, “Breaking Through” refers to the voyage of scientific exploration and research. It draws prominence to qualities like innovation, creativity and determination, which are the hallmarks of a scientist undertaking this journey. Secondly, “Breaking Through” also celebrates the accomplishments of numerous scientists who have achieved radical breakthroughs in their scientific research.

Bringing together 91 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, thereby gaining an insight into the lives of researchers and also first-hand experiences of working with complex laboratory equipment. Participants also engaged in an inspiring conversation with A*STAR scholars, which helped them obtained an outlook of the

Ms Indranee Rajah (Senior Minister of State for Law and Education) was impressed with the poster display.
potential science scholarships awaiting them.

At NTU, the delegates visited the School of Biological Sciences, School of Physical and Mathematical Sciences, and School of Civil and Electrical Engineering. The participants were engaged in hands-on activities like the levitation of superconductors on magnets, the action of the tesla coil, purification of raw water and a CSI workshop organised by the facilitators.

After the attachment, the participants engaged in a discussion with a distinguished panel of speakers. They included Nobel Laureates Prof Albert Fert, Prof Douglas Osheroff and Prof Danny Shechtman; Fields Medalist Prof Vladimir Voevodsky; and Prof Artur Ekert (Director, Centre for Quantum Technologies). Chaired by Prof Bertil Andersson (NTU President), the discussion include how science should be taught in schools and where science would be headed in the future. Interestingly, many of the Nobel Laureates started their journey toward scientific exploration with experiments in the backyard!

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Another highlight of ISYF was the Nobel Forum held on Day 4. We were honoured to have Ms Indranee Rajah, Senior Minister of State for Law and Education, to grace the event. In her opening speech, she defined “curiosity, creativity and courage” as the key qualities young scientists need in order to generate their own triumphs of tomorrow. These qualities would spur young scientists to be open-minded, ask questions and seek answers about the world, and engage one’s creative capacities to adapt to changes in our world. The Nobel Laureates also provided words of encouragement for budding researchers. “Find a peak in your life, and be an expert in it,” Prof Shechtman said aptly; a passion for science and a monopoly of knowledge is the driving force behind a successful researcher. At the same time, he reminded participants that gaining broad knowledge is as important as developing an area of strength. From the Nobel Forum, participants gained enlightening insights of what a breakthrough entails.

After 5 days of scientific learning, discovery and fun, the event was concluded with a Closing Ceremony dinner at Conrad Centennial Hotel. In his closing speech, Guest-of-Honour, Mr Lim Chuan Poh (Chairman of A*STAR) urged all students to continue their paths towards science research, and even consider Singapore as one of their pit...
stops to further their careers in research. 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 peers. ISYF has provided participants with a rare chance to interact with students from all over the world. 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.

All in all, it is hoped that through the sharing of knowledge and experience by Nobel Laureates, eminent scientists and peers, the participants would leave the Forum inspired and geared up to pursue their own breakthroughs and leave their mark on humanity and society. As Prof Albert Einstein once said in his time of glory, “Try not to become a man of success, but rather try to become a man of value.”

As Prof Osheroff said, “Research is the process of asking questions about nature.” You should pin-point your aim in areas that are not fully discovered, and combine specialties from different fields. To encourage us, the professors advised us not to give up easily since by answering each question, we may be rewarded in the pursuit of knowledge. As I am interested in doing research, I think this advice was important to me. This prompts me to work hard in all fields and build on my general knowledge, as there are no fixed boundaries of subjects when it comes to decoding the secrets of nature.

Catherine Lung
Diocesan Girls’ School, Hong Kong

Maybe what I’ve learned most from this ISYF are not learning points. Most of them are ways of thinking, the Nobel Laureates’ point of views and perceptions while working on a research. It was such a great experience to meet many people with different points of view. I learned so many things from them during this ISYF 2013. Thank you so much for everything. Go ISYF!

Audrey Willis
Santa Laurensia High School, Indonesia
Science is driven by individuals, but the success of their pursuits depends on their relations to other scientists and on the ambience of the laboratory environment. Nowhere can the importance of the culture of science be understood better than by studies of the discoveries by scientists awarded Nobel Prizes in the natural sciences. The Nobel archives can be made available for scholarly studies, albeit only after 50 years. In a book entitled *Nobel Prizes and Life Sciences* published by the World Scientific Publishing Co. I discussed prizes awarded until 1959. And in another book to be produced in the autumn of 2013, *Nobel Prizes and Nature’s Surprises*, further prizes awarded until 1962 will be reviewed.

1962 was an important year in the history of the Nobel prizes. In chemistry, Professors Max Perutz and John Kendrew were recognised for their studies of globular proteins by crystallography. And in physiology or medicine, Dr Francis Crick, and Professors James Watson and Maurice Wilkins were praised for their discovery of the structure of DNA. The latter discovery had appropriately been described as the largest paradigmatic shift in biology since the 1859 presentation of Darwinian evolution occurred. It was eventually understood that it was nucleic acids and not proteins that carried the genetic information. The full understanding of the double-helix structure of DNA with two anti-parallel strands held together by two kinds of nucleotide base pairs was based in part on crystallographic information and in part on chemical knowledge. However the two scientists, Prof Watson and Dr Crick, who were the first to deduce the correct structure on 28 February 1953, were neither crystallographers nor chemists, but using their combined remarkably creative minds, they hit on the right solution. In later developments, they dominated the rapidly emerging field of molecular biology.

Since 1962, many Nobel Prizes in physiology or medicine and also in chemistry have identified the milestones in the advance of the life sciences and there is much more to come. Paradoxically, the widening insights into the structure and operation of genes have made it more difficult to define fundamental concepts like what a gene is and what life is. The life sciences will be a hot field for research for a foreseeable future. Widening our insights into the close relations of all humans to each other and to other forms of life will have a major impact on how we manage existential problems and how we build a world on trust, respecting the diversity and dignity of humans. It serves to remind that humans have come to dominate life on Earth and hence we need to use our rapidly widening scientific insights to become good stewards.
**2nd Complexity Conference: “A Crude Look at the Whole”**

by Jan Vasbinder Director of Complexity Program, NTU

In his review of John Holland’s latest book, *Signals and Boundaries*, Christoph Adami\(^1\) wrote that “Complex systems do not easily lend themselves to analysis, the process of taking apart a system and examining its components individually. If taken apart, many complex systems lose precisely the character that makes them complex. The essence of these systems then, seems to lie not in the nature of their components but in how the components interact—across different hierarchies, in synergistic and antagonistic manners.”

This quote elegantly defines complexity as “a lack of simplicity”, simplicity being a condition in which you can study things in isolation. It also points to the central questions addressed by complexity science: What makes the whole more than the sum of its parts, what is this more, where does it come from?

Answers to these questions, said Prof Murray Gell-Mann\(^2\) (Nobel Laureate in Physics, 1969; Lee Kong Chian Distinguished Professor) in 1990 “cannot be found by determining in advance a set of properties or aspects that are studied separately and then recombining those partial approaches in an attempt to form a picture of the whole. Instead, it is necessary to look at the whole system, even if it means taking a crude look, and then allowing possible simplifications to emerge from the work.”

He also said, “Our world is a huge complex system consisting of an enormous number of interacting natural, social and human engineered systems. Understanding such systems and their interactions requires rigorously sharpened brains from all scientific disciplines. The major challenge for a maturing complexity science is to develop interactions between these scientific disciplines that match the interactions it intends to study.”

With that in mind, the Complexity Program at NTU organised its second annual conference, “A Crude Look at the Whole” with support from IAS. Held at the Nanyang Executive Centre from 3 to 5 March 2013, the conference was well attended by more than 370 local and overseas participants from academia, government agencies and industry. 12 world-class speakers gave insightful and thought-provoking talks and illustrated the relevance and importance of complexity science in every possible field of study, from curiosity and innovation to diversity and repetition, from resilience for human development to complexity in governance. Each talk was followed by lively and interactive discussions. The twelve speakers were:

1. Murray Gell-Mann (Santa Fe Institute)
2. Robert Axelrod (University of Michigan)
3. Helga Nowotny (ETH Zurich)
4. Kristian Lindgren (University of Technology)
5. John H. Holland (University of Michigan)
6. Douglas H. Erwin (Smithsonian Institution)
7. Ying-Yi Hong (Nanyang Technological University)
8. Peter M. A. Sloot (University of Amsterdam)
9. Simon Levin (Princeton University)
10. Johan Rockström (Stockholm University)
11. Wang Xian Feng (Nanyang Technological University)
12. Peter Ho (Urban Redevelopment Authority, Singapore)

Plans for the third conference in March 2014 are already underway and promises to be even better and more exciting than the last. So stay tuned!

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2. Murray Gell-Mann received the 1969 Nobel Prize in physics for his work on the theory of elementary particles
“Our world is a huge complex system consisting of an enormous number of interacting natural, social and human engineered systems.”

Prof Murray Gell-Mann
The Story of Quarks

Discovery Of The Basic Constituent Of The Universe

Cultivate the habit of asking “Why Not?” was the advice given by the Father of Quarks, Prof Murray Gell-Mann (Nobel Laureate in Physics, 1969; Lee Kong Chian Distinguished Professor) to an audience of nearly 200 students, professors, and members of the public who were present for a special public lecture on “The Story of Quarks”. The talks by Prof Murray Gell-Mann and his close collaborator, Prof Harald Fritzsch (University of Munich), were held at CREATE, University Town on 5 March 2013.

Co-organised by IAS and the National Research Foundation, the talks aimed to introduce quarks – the basic constituent of the universe, and their properties. Both professors are renowned for their contributions to the scientific discoveries of colour quantum number in the 1970s. Prof Fritzsch has been working closely with Prof Gell-Mann since his post-doctorate studies.

Prof Gell-Mann was once asked, “How did you come to think about quarks?” The answer he gave was that given the patterns, it was fairly obvious that quarks were a good possibility. The difficulty in justifying their existence was the fact that their presence violated three basic established beliefs in physics at that time. They are:

1) The neutron and proton are elementary particles, NOT composed of simpler constituents.

2) Elementary particles all have integral charges, such as 0,1,-1, in units of the proton charge.

3) Elementary particles cannot be trapped inside colour-neutral objects such as nucleons.

These three statements were subsequently proven to be incorrect.

The strong force that binds quarks together acts on “colour”, just as electromagnetism acts on electric charge. Just as the electromagnetic interaction is mediated by

(From left) Dr Low Hwee Boon (IAS), Prof Harald Fritzsch, Prof Phua Kok Khoo (Director, IAS) and Prof Murray Gell-Mann.
quarks. Each quark carries a fraction of a proton’s electric charge. Quarks come in six different varieties that have quirky names — up, down, charm, top, bottom and strange. It is not hard to see that the neutron, the proton and other such states are composed of quarks, but for those who are not convinced, there are three prohibitions to embracing the idea of quarks, according to Prof Gell-Mann. “One, believing that neutrons and protons are the elementary particles; two, believing charges to be integral instead of fractional; three, believing that elementary particles can’t be trapped within neutrons and protons.”

One must let go of classical ideas of physics to understand quark theory, added Prof Gell-Mann. On the future direction of physics, Prof Gell-Mann said: “The holy grail of physics is to find the theory that unifies all interactions (between particles), including gravitation. The search for this unifying theory would be a very important future direction for physics. It also needs to be combined with further work on the evolution of the universe. We’ll see how it works out. It’s a very exciting hunt, the hunt for further unification.”

Prof Gell-Mann and Prof Fritzsch also discussed their thoughts on the teaching of science and physics. “There are many things that learning science can accomplish, and we should not neglect any of them,” said Prof Gell-Mann. “One thing is to lay the groundwork for application, but understanding the fundamentals and the basic laws is an important part of education as well, because really serious students are curious, and pure science is driven by curiosity.”

On the purpose of education, he said: “Is (education) just a utilitarian occupation? We’d like to think that’s not the case, that to some extent, it’s utilitarian and to some extent, it’s about being an educated person.”

The current teaching of physics can always be improved, according to Prof Fritzsch. “We need better teachers,” he said. “Good physicists become physicists, they don’t become teachers.”

Prof Gell-Mann is a strong proponent of collaborating across disciplinary lines. He dislikes the “departmentalisation of knowledge”, and co-founded the Santa Fe Institute in New Mexico, United States, as an alternative model of research and learning.

“Instead of thinking of something as a department, think of it as a subject, and think of the barriers between departments as an impediment to learning, teaching and understanding, and in many cases, they have been,” said Prof Gell-Mann.

Research conducted at the Santa Fe Institute is based on cross-disciplinary collaboration, which brings together the expertise of researchers with varied backgrounds, he added. On the success of the Santa Fe model, Prof Gell-Mann said more people have come to believe in it and have set up similar institutes. “Imitation is the sincerest form of flattery,” he said.

Asked why he loved physics so much that he made it his career, Prof Gell-Mann said: “These laws that we study are the laws obeyed by all matter everywhere in the universe. ... There’s also a connection between (these laws) and the study of the history of the universe.”

On the perception of particle physics as a challenging subject to study, Prof Gell-Mann said: “I don’t believe (particle physics) is so hard to understand, but it has that reputation. “The best thing is to not be intimidated by the subject. I think a lot of it depends on the mindset. If you think, “This is just another theory, and I can learn it the way I learn other things”, then you can learn it.”

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Media coverage on the Quarks public lecture. This article first appeared in TODAY on 8 March 2013.
The School on Modern Topics in Condensed Matter Physics was held at NTU from 28 January to 8 February 2013. The school was co-organised by IAS and the Physics of Novel Electronics at NTU, the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, Italy, Centre for Quantum Technologies and the Graphene Centre at the National University of Singapore (NUS) and Office of Naval Research Global.

There were 87 participants for the School selected from more than 250 applicants. 37 attendees were from countries such as India, Sri Lanka, Pakistan, Thailand, Vietnam, Philippines, Iran, Taiwan, Turkey, Malaysia, USA and Japan. There were also 50 local masters and PhD students, postdocs and researchers from NTU, NUS and the Agency for Science, Technology and Research (A*STAR).

Distinguished lecturers of the School included Professors Albert Fert (Nobel Laureate in Physics, 2007), Laurens Molenkamp (University of Würzburg), Peter Fulde (Max-Planck-Institut für Physik Komplexer Systeme), Gabriel Aeppli (University College London), and Ng Tai Kai (Hong Kong University of Science and Technology), just to name a few. Many of them made a great effort in sharing their insights and perspectives with the participants.

The School introduced modern concepts and methods in condensed matter physics, with a special focus towards physics in low dimensions. The choice of topics was deliberately made fairly broad, covering areas such as quantum magnetism, frustration and fractionalisation, new topics in superconductivity, properties and fabrication of interfaces and heterostructures, topological phases and topological insulators, two dimensional crystals and fundamental physics and applications of graphene, spintronics, and new ideas for solid state quantum computation, both from experimental and theoretical points of view.

A presentation by Dr Hazel Khoo (Director, Science and Engineering Research Council, A*STAR) on current research in Singapore, a lab visit to the Graphene Centre, as well as advice from Dr Nicky Dean, Nature Communications Editor, rounded the purely scientific part of the lectures. The participants also presented their own works in an extended poster session and a number of short contributed talks.

The responses from the participants were very positive; they enjoyed both the scientific ambience and the professional and cultural exchanges during the School.

I was impressed by the high quality of the talks as well as the efforts by the speakers to engage the students and postdocs in the audience. Co-organising with ICTP is really a great idea; it is a wonderful opportunity for local researchers to get to know potential students/postdocs, as well as to network and learn new fields. I look forward to seeing more of such events in the future!

Su Ying Quek
Institute of High Performance Computing, A*STAR
01. Prof Antonio Castro-Neto (Director, Graphene Research Centre, NUS) gave a warm welcome to the participants. | 02. The students of the school were both attentive listeners and active participants. | 03. Participants admiring and studying the posters put up by their peers. | 04. Prof Albert Fert (Nobel Laureate in Physics, 2007) delivering his lecture on spintronics.

The school provided me with priceless knowledge by laying the groundwork for future research in emerging physics. It zeroed in on the exciting phenomena discovered recently, including unpublished work and shed light on many aspects of both experimental and theoretical condensed matter physics. I also had a wonderful experience participating in the lively interactions and discussions at all levels: faculty, postdocs and graduate students.

James Lourembam
School of Physical and Mathematical Sciences, NTU

The school was very resourceful, and I learned a lot from the lectures on hot topics in low dimensional condensed physics, which was very helpful in my current research. The school was very successful thanks to the considerate arrangement of the organisers. Thank you very much!

Xin Luo
Institute of High Performance Computing, A*STAR
IAS - CERN Workshop on Particle Physics and Cosmology — Status, Implications and Technology

Following the success of the 1st IAS-CERN School held in January 2012, IAS and CERN came together once again to co-organise a joint Workshop on Particle Physics and Cosmology — Status, Implications and Technology. The 3-day workshop was held in NTU from 25 to 27 March 2013.

The workshop was a highly successful sequel, attracting over 80 participants ranging from postdocs to high school students. Many experts in their respective fields were invited to give lectures and provide updates on their research projects. The distinguished speakers included Professors Albert De Roeck (CERN), Chang Ngee-Pong (CUNY), Harald Fritzsch (University of Munich), Mark Kruse (Duke University), Ernest Ma (University of California, Riverside), Serguey Petcov (SISSA/INFN and University of Tokyo), Emmanuel Tsesmelis (CERN), Xing Zhi-Zhong (Institute of High Energy Physics, Chinese Academy of Sciences), Wang Yi-Fang (Institute of High Energy Physics, Chinese Academy of Sciences) and many more.

One of the highlights of the workshop was a panel discussion featuring international co-operation in physics research in the Asia Pacific region. Short presentations were given by regional representatives summarising the status of particle physics research in their respective countries and the plans for the future. It was then followed by a roundtable discussion with the aim of identifying areas of common interest across the region to facilitate closer collaboration.

The recent discovery of the elusive Higgs boson has spurred scientists to answer bigger questions about the universe. “Without the Higgs field, the universe would be a very different place,” said Duke University physicist Prof Mark Kruse, one of the many scientists on the Atlas project at CERN. CERN senior research scientist Prof Albert de Roeck said that the Large Hadron Collider is being shut down slowly to prepare it for upgrading. The next phase will start in 2015. The upgrade will enable collisions to produce heavier particles — some of which could be possible candidates for dark matter, the invisible stuff that makes up much of the universe’s mass.

Overall, the workshop was a resounding success and many participants are looking forward to the next IAS-CERN collaboration.

I am very glad to have the opportunity to attend the IAS-CERN workshop. I have learnt a lot that cannot be learnt in ordinary classes. It is extremely important to my scientific career to keep abreast of the latest discoveries and advances in these fields. I appreciate the hard work done by everyone for this wonderful event.

Leong Wui Seng
School of Physical and Mathematical Sciences, NTU
12 panel speakers from the Asia Pacific countries at the discussion on international co-operation in physics.

‘God particle’ may shed light on dark matter

Feature article by The Sunday Times on 28 April 2013.
The Singapore-China Joint Symposium on Research Frontiers in Physics is a traditional forum and has become an annual event for physicists from China and Singapore to present and discuss their latest research advances in various fields of physics. It aims to address challenges and opportunities in current physics research, foster better communications, and encourage collaborations on research and graduate education.

Following the successful 8th Symposium meeting held in Guangzhou, China in 2012, the 9th Singapore-China Symposium was held this year from 28 to 29 June 2013 at the School of Physical and Mathematical Sciences (SPMS), NTU. To stimulate intensive discussion, this year’s symposium focused on two important and active research areas in Physics: Photonics and Condensed Matter Physics. The symposium was jointly organised by IAS, SPMS and the Department of Physics at the National University of Singapore.

With nearly 200 participants and speakers attending the symposium and only two days to cover all the topics in detail, it was no wonder that the schedule was packed to the brim with plenary sessions in the morning and four parallel sessions in the afternoon.
Prof Phua Kok Khoo (Director, IAS) delivered the opening address for the symposium. He emphasised the need for physicists in Singapore and China to retain close ties with one another, and continue to make use of the opportunity the symposium provided to establish new international collaborations and projects.

The programme featured talks by eminent scientists such as Professors Lin Haiqing (Director, Beijing Computational Science Research Center), Wang Xuehua (Vice Dean, School of Physics and Engineering, Sun Yat-Sen University), Tong Limin (Chair, Department of Optical Engineering, Zhejiang University), Zhang Baoping (Chair, Department of Electrical and Electronic Engineering, Xiamen University), Andrew Wee (Dean of Science, NUS), Nikolay Zheludev (Centre for Disruptive Photonics Technologies, NTU), Federico Capasso (Harvard University) and many others.

Indeed, the spirit of collaboration, friendship, and forging of closer ties was evident throughout the symposium, with discussions continuing after lectures and stretching into coffee breaks and lunches. The speakers also enjoyed a sumptuous feast at the banquet and a unique dinner experience on board the Imperial Cheng Ho Cruise.

The symposium provided a great opportunity to listen to lectures given by prestigious scholars from Singapore and China. Their enlightening talks covered frontiers of photonics such as metamaterials and quantum optics. We also seized the chance to discuss academic problems with them face-to-face, which helped a lot in our research.

Xu Hongyi
School of Physical and Mathematical Sciences, NTU

As a student whose interest is in the research field of condensed matter physics, the experimental and theoretical works presented by the speakers on graphene and topological insulators were very helpful to me. The chance to interact with top level researchers also enhanced my interest in my current field of research. The symposium was indeed a good opportunity for me to learn and explore.

Shen Xiaonan
School of Physical and Mathematical Sciences, NTU

I learnt many new things from the symposium. There were various fantastic topics in the session of photonics, such as the Invisibility cloak, Lasing and Plasmonics, which have broadened my horizon in the field of light-matter interaction. Since my research topic is closely related to this session, I gained insights about the work done by the eminent scientists which greatly inspired me in my research study.

Wang Yue
School of Physical and Mathematical Sciences, NTU
The Asia Pacific Center for Theoretical Physics (APCTP) Workshop on Multiferroics was first held in Korea and hosted by Pohang University of Science and Technology in December 2008. It aims to provide a common platform for researchers and young students in the Asia Pacific region to gather and share their research findings, as well as to keep up-to-date on current developments and future directions in the field of multiferroics. Subsequent workshops were hosted by different countries in the Asia Pacific region such as Korea, Taiwan, Japan and China.

The 5th workshop was co-hosted by IAS together with the School of Physical and Mathematical Sciences (SPMS), and the School of Materials Science and Engineering from 22 to 24 May 2013. More than 80 speakers and participants from all over the world congregated at SPMS to participate in the 3-day workshop.

Multiferroics are materials that simultaneously exhibit both magnetic and ferroelectric properties. Typically, multiferroics are perovskite transition metal oxides and they are a group of
interesting and potentially important class of materials. An increasing amount of theoretical and experimental efforts have been put into the understanding and discovery of novel multiferroic materials with improved functionality for practical usage. Multiferroic structures in bulk form are already being explored for high-sensitivity field sensors and electrically tunable microwave devices and oscillators. Thin films on the other hand, can be useful for magneto-electronic devices including low dimensional spintronic devices with electric field tunable functions.

Many renowned experts from the field of multiferroics were present at the workshop. They shared with the participants the current progress of research and possible future developments of multiferroics. Some of the invited speakers included Professors Sang Wook Cheong (Rutgers University), Daniil Il’ich Khomskii (Cologne University), Neil Mathur (Cambridge University), Li Jianqi (Institute of Physics, Chinese Academy of Sciences), and many others.

During the workshop, the sharing of research results and developments brought about many exciting discussions among the speakers and participants. From all the hype and active dialogues generated during the workshop, we can be sure to look forward to more exciting progress in this field in the near future. The 6th APCTP Workshop on Multiferroics is scheduled to be held in India in 2014.

Without a doubt, the APCTP workshop was a great experience for me to listen to scientists at the forefront of the multiferroics research field. The workshop gave me a good update about the activities and developments in the field of multiferroics. It was a nice experience at the workshop and in Singapore.

P. Anil Kumar
Uppsala University

The thing about APCTP that most impressed me was the fact that so many top scientists in the multiferroics research field came and presented their research activities. This was a really good opportunity for me to update myself about the developments in this field and broaden my vision as well. It was a great experience to have the workshop in Singapore. Thanks to the organisers!

Lin Weinan
School of Physical and Mathematical Sciences, NTU

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Lin Weinan
School of Physical and Mathematical Sciences, NTU

Without a doubt, the APCTP workshop was a great experience for the attendees. In this workshop, we learned about the basics in the multiferroics research field, and also had discussions with the invited scientists on these specific hot topics. This workshop included talks on theoretic discussions, experimental analyses and modelling simulations, which helped us gain important insights to explore the underlying physics. Besides that, it also offered an opportunity to communicate with many eminent scientists. If this workshop can offer a much detailed catalogue, such as the abstracts or related references, it would be much better. Finally, thanks again to the organisers for the great effort in putting together the wonderful workshop.

He Mi
School of Physical and Mathematical Sciences, NTU

Speaker and participants of the APCTP Workshop.
International Workshop on Determination of the Fundamental Parameters of QCD

by Cesareo Dominguez The University of Cape Town

The International Workshop on Determination of the Fundamental Parameters of QCD (Quantum Chromodynamics) was organised from 18 to 21 March 2013 at the Nanyang Executive Centre.

The topics were highly focused on theoretical and experimental issues pertaining to the determination of quark masses, and the strong running coupling of QCD. New theoretical results were presented in the framework of lattice QCD simulations, QCD sum rules, and chiral perturbation theory predictions for light quark ratios. Experimental results related to charm- and bottom-quark masses were also thoroughly covered. Information on the strong running coupling, at various energy scales and from a variety of sources, was discussed at several talks. The present status of the hadronic contribution to muon magnetic moment anomaly (g-2) was also reviewed in one talk.

The workshop was designed and planned to allow for plenty of time for discussions and interaction among speakers and participants in the afternoons.

Delight was written over the speakers and participants' faces.
The Institute of Physics (UK) - Institute of Physics (Singapore) Joint Workshop on Nanoscience is an event that aims to provide a common platform for the sharing and discussion of research in physical sciences in Singapore. It was held from 4 to 6 March 2013 at the School of Physical and Mathematical Sciences (SPMS) in conjunction with the annual meeting of the Institute of Physics, Singapore (IPS). The event was jointly organised by IPS, SPMS, the Department of Physics at the National University of Singapore, and the Institute of High Performance Computing at A*STAR, with the support of IAS and the Centre for Quantum Technologies, NUS.

The meeting hosted visitors from photonics clusters in Southampton, UK, members specialising in nanoscience and technology from the Institute of Physics in UK, and many local scientists with research interests in the physical sciences. Some of the experts who gave talks at the meeting include Professors David Richardson (University of Southampton), Nikolay Zheludev (Centre for Disruptive Photonics Technologies, NTU), Philip Moriarty (University of Nottingham), and Barbaros Ozyilmaz (Department of Physics and Graphene Research Center, NUS).

This year’s meeting featured a broad range of topics, which included subjects such as photonics, nanoscience, plasma science, and quantum information and systems. With over 80 technical talks and 60 poster contributions, the programme was stretched to a full three days.

In conjunction with the recent opening of the Centre for Disruptive Photonic Technologies (CDPT) at NTU and the new focus of competitive research, a special...
symposium with four sessions dedicated to research in this area was organised. One of the highlights of the programme was a panel session with esteemed representatives from the science and technology sector, where they discussed at length the impact of photonic technologies in Singapore.

A poster pitch competition was also held with the aim of making poster sessions more attractive and competitive. Poster presenters were given three minutes each to advertise their works to the audience. Interested parties each met up with the researchers later on. The Best Poster Award jury also made their choices based on these presentations.

The meeting was highly successful and fruitful, with many stimulating conversations, sharing of innovative ideas, and opportunities created for future collaborations. Plans to organise the IPS Meeting 2014 are already well underway.
The Memorandum of Understanding (MOU) signing ceremony between the Institute of Advanced Studies (IAS) and the University of Science (HCMUS), VNU- Ho Chi Minh City was held on 27 June 2013 at the Nanyang Technological University, Singapore. The MOU serves as a foundation for the promotion of cooperative activities including the exchange of scientific information, visits and exchange of faculty and students, and the organisation of joint workshops and seminars.

Prof Nguyen Van Hieu (Head, Office of International Relations, HCMUS) visited IAS from 26 to 29 June 2013 and he was glad that the MOU opened a new chapter in fostering closer ties between the two institutions. In relation to his visit, he also visited the NTU School of Physical and Mathematical Sciences and the A*STAR’s Data Storage Institute.
Prof Bruce McKellar: Experimental Detection of the He-McKellar-Wilkens Phase

by Low Hwee Boon Institute of Advanced Studies, NTU

During a trip to Singapore to discuss the organisation of the 28th General Assembly of the IUPAP (International Union of Pure and Applied Physics) at IAS, President-Designate of the IUPAP, Prof Bruce McKellar managed to free up some time to give a colloquium entitled “Experimental Detection of the He-McKellar-Wilkens Phase” at the School of Physical and Mathematical Sciences (SPMS). The colloquium, held on 23 April 2013, was jointly organised by IAS and SPMS.

Prof McKellar is an Honorary Professorial Fellow at the School of Physics, University of Melbourne, where he is also an associate of the Centre of Excellence for Particle Physics at the Terrascale. His work focuses on particle physics, but his research also covers many other aspects of physics such as atomic physics, solid state physics, statistical mechanics and mathematical physics. He has published papers in journals ranging from pure mathematics and physics to meteorology and photographic engineering.

Prof McKellar began by explaining the significance of the Aharonov-Bohm effect. Electric and magnetic fields ($\mathbf{E}$, $\mathbf{B}$) are uniquely described by Maxwell’s equations. In the recasting of Maxwell’s classical electromagnetic theory as a gauge theory, description of electromagnetic phenomena can be simplified by the introduction of the electromagnetic scalar potential $\Phi$ and vector potential $\mathbf{A}$.

To write electric and magnetic fields in the form of potentials is useful because only four components are needed. For instance, one scalar field and three
components of vector field can be used to describe an electromagnetic field. In general, an electromagnetic field usually consists of six components (three components for each vector field).

Until the beginning of the 20th century, it was widely believed that potentials were only a mathematical construct to simplify calculations and that they had no physical significance. With the development of quantum mechanics however, this view came under scrutiny because the wave-function equation of quantum mechanics didn’t contain fields, but potentials. So a new question arose: which description of electromagnetic phenomena was more representative? Was it by using electric and magnetic fields, or by scalar and vector potentials?

This issue was resolved by the Aharonov–Bohm thought experiments conducted in 1959, which eventually led to experimental realisations. The Aharonov–Bohm effect is a quantum mechanical phenomenon in which the wave function of an electrically charged particle is affected by an electromagnetic field ($\mathbf{E}$, $\mathbf{B}$), despite being confined to a region in which both the magnetic field $\mathbf{B}$ and electric field $\mathbf{E}$ are zero. It acquires some additional phases when travelling through space with only potentials and no electromagnetic fields.

In the late 80s and early 90s, Prof McKellar and his collaborator, Prof He Xiao-Gang, calculated the electric dipole moments of the neutron, electron and other particles in many models related to CP violation. With electric dipole moments in mind, they realised that the dual of the Aharonov-Casher phase (acquired when a magnetic dipole moves around a line of charges), was the phase acquired when an electric dipole moves around a line of magnetic monopoles. They devised a consistent theoretical model and published the result in 1993. In 1994, Prof Martin Wilkens independently reached the same conclusion. This phase has become known as the He-McKellar-Wilkens (HMW) phase.

In October 2012, a paper entitled “He-McKellar-Wilkens Topological Phase in Atom Interferometry” was published in Physics Review Letter, reporting an observation of the HMW phase of about 30 mrad. After reviewing the original He-McKellar proposal, Prof McKellar described how it turned out to be possible to observe the HMW phase without having monopoles to hand. He went on to discuss the topological nature of phases and suggested alternative experimental arrangements, developed in collaboration with Professors He Xiao-Gang and Tony Klein.
Prof Tan Chung-I: Holography, Graviton and High Energy Scattering at LHC

by Xiong Chi, Institute of Advanced Studies, NTU

Exploration of Gauge-String Duality, also known as AdS/CFT Correspondence, or, more broadly, Holography, has exploded in recent years, from heavy ion collisions to condensed matter physics. In relation to his visit to IAS in January 2013, Prof Tan Chung-I gave a talk entitled “Holography, Graviton, and High Energy Scattering at LHC” on 7 January 2013 at the School of Physical and Mathematical Sciences (SPMS) at NTU.

Prof Tan is currently with Brown University, USA, and was previously the chair of the Physics Department from 2004 to 2010. He taught at Princeton University before joining the Brown faculty. His research focuses on non-perturbative Quantum Chromodynamics (QCD), which serves as the fundamental theory for studying particles like protons, neutrons, pions, etc. Recently, he is interested in the gauge/string duality and the application of string theory in exploring the physical energy scale covered by the Large Hadron Collider (LHC).

In his talk, Prof Tan briefly reviewed fundamental interactions, including gravity and strong interaction. He then introduced the AdS/CFT Correspondence and the more general idea of holography. In particular, the strongly-coupled gauge theories in four-dimensional Minkowski spacetime can be studied via a weakly-coupled gravity/string theory in higher-dimensional Anti-de Sitter (AdS) spacetime.

How is it related to the physics at LHC? Prof Tan went on to describe the physics of high energy scattering and topics such as S-matrix, cross-section and Regge theory, which were intensively studied in the 1960s and 70s. In an example, he mentioned the Chou-Yang model and a paper written by Prof Phua Kok Khoo and Dr Low Hwee Boon of IAS and their collaborators, entitled “The Implication of Chou-Yang Model in Pi-p Elastic Scattering” (Phys. Rev. D17 (1978) 802). In fact, string theory
emerged by the end of the 1960s from the dual models of hadron resonances, and string S-matrix scattering amplitudes agreed with those obtained in meson scattering experiments.

Among many applications of the gauge/string duality, Prof Tan focused on the connection of graviton and Pomeron, which was introduced in the scattering theory about 40 years ago. The Pomeron, abbreviation for Pomeranchuk trajectory, may correspond to a physical particle of spin 2 under certain conditions. Could it be associated with a graviton? Together with Brower, Polchinski and other collaborators, Prof Tan showed that in gauge theories with string-theoretical dual descriptions, QCD Pomersons can be considered as AdS-gravitons, i.e. metric fluctuations in the AdS spacetime. Hence, their work (refer the highly cited paper “The Pomeron and gauge/string duality”, JHEP 0712, 005 (2007)) provided meaning for the Pomersons nonperturbatively from first principles.

Prof Tan’s one-hour talk covered many aspects of quantum field theory and string theory, which drew several questions from the audience and interests from the students. It was very informative to those who have a keen interest in the area, and also provided researchers from different areas an insight and deeper appreciation of the developments in string theory.

In his talk, Prof Tan cited a paper written by Prof Phua, Dr Low and their collaborators.

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**Implication of the Chou-Yang model in π p elastic scattering**

S. C. Chau, S. Y. Lo,* and H. B. Low,
Department of Physics, Nanyang University, Singapore 22

K. K. Phua
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(Received 1 February 1977)

With some knowledge of the pion form factor, we study πp elastic scattering within the Chou–Yang model. We find it agrees very well with recent Fermilab measurements and we predict the existence of a dip at =1.5 GeV. The sensitivity of the dip structure due to the variation of the shape of the pion form factor is studied.

1. INTRODUCTION

The interaction strength is given by normalizing to the total-cross-section measurements:

\[ \sigma_{\pi p}(t) = \frac{\alpha_{s}(\sqrt{s})}{4\pi}. \]  

In his talk, Prof Tan cited a paper written by Prof Phua, Dr Low and their collaborators.
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IAS Research Highlights

by Xiong Chi, Michael Good, Su Haibin, Kerson Huang and Low Hwee Boon
Institute of Advanced Studies, NTU

Exciting work is going on at IAS in the Nanyang Technological University, Singapore. The cosmological studies of the IAS research group focus on the interdisciplinary research areas of cosmology, particle physics and condensed matter physics. Interesting quantum gravitational phenomenology, such as particle creation in a time-dependent gravitational field and cosmological superfluidity, illustrates how gravitation and quantum field theory interact in new and enlightening ways.

Amplification of quantum field fluctuations is an unavoidable consequence in a strongly time-dependent gravitational field. This amplification emphasises the importance of the effect of the dynamics of spacetime on quantum fields. Physical implications of amplification are black hole evaporation, acceleration radiation, accelerated boundary radiation, cosmological particle creation and the inflationary model of the universe.

The discovery of the Higgs further confirms that the vacuum of the universe is alive with the dynamics of quantised scalar fields. The cosmological effects of the changing phase of complex scalar fields give rise to interesting physics such as superfluidity, vorticity and quantum turbulence.

One of the effects being studied at IAS is the superfluid behaviour of a quantised scalar field living in a curved spacetime outside a rotating black hole. The behaviour of a superfluid in a rotating BTZ blackhole in the three-dimensional spacetime is of interest and the Kerr blackhole with superfluid in the four-dimensional spacetime will be investigated.

This is a consequence of the study of the cosmological vacuum, dark matter and dark energy with a complex scalar field, an interesting scenario previously proposed by members of the IAS research group, comprising Prof Kerson Huang, Dr Low Hwee Boon and Dr Tung Roh Suan.

The above scenario was formulated and solved using an initial-value problem for big-bang cosmology, based on Einstein’s equation in Robertson-Walker metric, with a Halpern-Huang quantum scalar field as source of gravity. The result is that the Hubble parameter decays in time according to a power law: $H \sim t^{-p}$ ($0 < p < 1$). This signifies accelerated expansion of the universe, indicating “dark energy”.

A nonlinear Klein-Gordon equation is used to describe the superfluid and its response to the galaxies, such as the emergence of the dark matter halo and the creation of vortex lattice due to galactic rotations (Fig 1).

Motions of the dark halo were also simulated and observed, such as the collisions between two galaxies and etc. (Fig 2). These have been included in the paper “Scalar-field theory of dark matter” (arXiv:1304.1595 [gr-qc], submitted to Phys. Rev. D). These studies are then

![Fig 1.](image-url)
generalised to the strong gravitational field cases, such as the superfluid in blackhole background and the gravitational collapse problem.

Some LHC-related physics, such as the QCD vacuum structure, quark-gluon plasma and their applications in early universe were also studied. Dr Xiong Chi applied the holographic method to the membrane configuration in the QCD vacuum (Phys. Rev. D86 (2012) 105020). He also proposed a new formulation for QCD flux tubes which the topological charge emerges naturally (Phys. Rev. D88 (2013) 025042).

Dr Michael Good’s research is motivated by the desire to understand the interaction of the dynamics of spacetime with quantum fields. Efforts are being directed to understanding the non-equilibrium radiation that occurs in the evolution of particle production from general forms of strongly time-dependent accelerations (Phys. Rev. D88 (2013) 025023). One exciting discovery so far has been the revelation of the precise form of dynamical acceleration required to produce thermal radiation from a boundary condition (IJMPA Vol. 28 No. 2 (2013)). The dynamics is unexpected because in the well-known Unruh effect, it is constant acceleration that gives rise to thermal radiation.

Biophysics is also being studied at IAS. Prof Kerson Huang and Prof Haibin Su are doing research focusing on the development and application of theoretical and simulation methodology to predict and explain the structure, properties, and behaviour of functional proteins. One ongoing project is to investigate energy transfer in α-helix, which consists of 32 alanine residues and is central toward understanding how proteins function, for instance, the intriguing function of the uncoupling protein in brown adipose tissue in non-shivering thermogenesis. The energy transfer pathways are being investigated by a non-equilibrium molecular dynamics method to elucidate the role played by H-bond, which will be further tested by the pump-probe technique to unravel ultra fast processes on a time scale of ps or fs.

Another major topic is the protein structural transformation, in particular, the conformation change from α-helix to β-sheet which is known to cause the prion disease. The free energy analysis is currently being conducted to address one fundamental question: how do the intermediate states facilitate or hinder the formation of three-dimensional native structure? The kinetics and dynamics of folding, and understanding of how the polypeptide chains attain its native state in a biologically relevant timescale, are also of interest. This study is tightly connected with the recent rapid advances in single-molecule fluorescence and force spectroscopy techniques which allow investigation of the folding and dynamics of single protein molecules, both at equilibrium and as they fold and unfold.
Twisted Photons Enable Precision Measurement

Novel optical devices that ‘twist’ and ‘untwist’ a beam of light enable a promising new measurement technique, as shown by researchers from Singapore, Italy and Spain. The international team published its results on 18 September 2013 in Nature Communications and has applied for a patent on the technology.

Light becomes twisted when the orientation of the light wave’s electric and magnetic field varies across the profile of the beam. The beam then spirals through space like a corkscrew and its photons acquire an ‘orbital angular momentum’ (OAM), separate to the spin associated with the light’s polarisation.

Researchers around the world have been exploring possible applications for OAM light, from increasing the density of data transmission down optical fibres to building new types of sensor. The collaboration involving Prof Kwek Leong Chuan...
A photonic polarisation gear stick. Image: Quantum optics group at Sapienza Universita di Roma.

(Deputy Director of IAS and Principal Investigator of CQT) and his former student Li Ying, now a postdoc at Oxford University in the UK, has shown how such light could increase the sensitivity of angular measurements over current state of the art almost 100-fold.

The trick relies on devices known as ‘q-plates’ designed and built by the Italian members of the team. These q-plates are patterned sheets of liquid crystal that act on the orbital angular momentum of light. Passing a circularly polarised beam through a q-plate adds twist, with the quantum ‘m’ of OAM acquired depending on the pattern in the plate. When the beam passes through the plate again, it is untwisted and the OAM is absorbed into the beam in a way that affects the phase of the light — the phase is multiplied by m. This is the ‘polarisarion gear’ effect that can be harnessed for measurement of angles. Because the phase change is multiplied by m, it becomes easier to detect.

In the work published in Nature Communications, the team report experiments for q-plates that can impart OAM up to 100. The researchers, supported by their respective Universities, have applied for a patent in Italy that covers this use of their q-plates.

“The technique is quantum-inspired in a historical sense,” said Prof Kwek, who was involved in the theoretical side of the work. It has long been known that entangled quantum particles could increase precision in measurement. The promise of quantum metrology is that the uncertainty of a measurement made with entangled N photons, the uncertainty would scale as 1/N. They show this experimentally in the Nature Communications paper with entangled states of two photons. But the quantum route is challenging because entangled states of many photons are hard to make — so it’s not efficient to make N big. Instead they note that a classical approach, which has uncertainty scaling as 1/(m√N), already offers big improvements in precision given that they can use their q-plates to make m as large as 100. The measurement is also robust to photon losses, a problem which derails attempts to make measurements with entangled states. The authors write in the paper that this classical approach is “immediately applicable to real world optical measurements”.


The Italian patent pending application (RM2013A000318, deposited 3 June 2013) is titled ‘Ultra-sensitive photonic tiltmeter utilising the orbital angular momentum of the light, and relevant angular measurement method’. 
FORTHCOMING EVENTS

22 to 25 November 2013
3rd Workshop on Standardisation of Chinese Physics Terminology
Beijing, China

19 to 23 January 2014
6th International Science Youth Forum with Nobel Laureates in Singapore
Hwa Chong Institution

19 to 24 January 2014
2nd Global Young Scientists Summit
Nanyang Technological University

10 to 13 February 2014
International Conference on Flavor Physics and Mass Generation
Nanyang Executive Centre, NTU

18 to 21 March 2014
3rd Physics and Mathematics Workshops for the Malaysian Chinese Independent High Schools Teachers
School of Physical and Mathematical Sciences, NTU

11 to 14 June 2014
3rd International Photosynthesis Workshop
Nanyang Executive Centre, NTU

23 to 27 June 2014
The 8th Joint Meeting of Chinese Physicists Worldwide (OCPA8)
School of Physical and Mathematical Sciences, NTU

22 to 23 July 2014
Workshop on the Chemistry of Energy Conversion: From Molecular Design to Advanced Materials
Nanyang Executive Centre, NTU

24 to 29 August 2014
8th Asian Science Camp with Nobel Laureates in Singapore
Nanyang Executive Centre, NTU

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

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