

Gell-Mann: quantum mechanics to complexity

A conference in Singapore held at the Institute of Advanced Studies, Nanyang Technological University, gathered former students and collaborators of Murray Gell-Mann to celebrate his 80th birthday with a retrospective of his achievements in various fields.

To celebrate Murray Gell-Mann's many contributions in physics in his 80th year, the Institute of Advanced Studies at Nanyang Technological University and the Santa Fe Institute jointly organized the Conference in Honour of Murray Gell-Mann, which took place in Singapore on 24–26 February. Aptly entitled "Quantum Mechanics, Elementary Particles, Quantum Cosmology and Complexity" to focus on Gell-Mann's achievements in these fields, the three-day conference was a festival of lectures and discussions that attracted more than 150 participants from 22 countries. Those in attendance included many of Gell-Mann's former students and collaborators. For a select few this was their second visit to Singapore, having attended the 25th Rochester Conference held there 20 years ago.



Murray Gell-Mann. (Courtesy Santa Fe Institute.)

The meeting began with a brief scientific biography of Gell-Mann presented by his close collaborator Harald Fritzsch of Ludwig-Maximilians University, who highlighted his main achievements. During the 1950s Gell-Mann worked with Francis Low on the renormalization group and with Richard Feynman on the V-A theory of weak interaction. The application of the SU(3) symmetry group to classify hadrons led Gell-Mann to predict the existence of the Ω^- particle in 1961; its subsequent discovery in 1964 paved the way to his receiving the Nobel Prize in Physics in 1969. Gell-Mann and George Zweig independently proposed quarks as the constituents of hadrons in 1964.

Gell-Mann studied the current algebra of hadrons together with various co-workers. In 1971 he introduced light-cone algebra together with Fritzsch, as well as the colour quantum number for quarks. A year later they proposed the theory of QCD for the strong interaction. In 1978 Gell-Mann, Pierre Ramond and Richard Slansky proposed

the seesaw mechanism to explain the tiny neutrino masses. Then, in around 1980, Gell-Mann switched his interest towards the foundations of quantum mechanics, quantum cosmology and string theory.

Multifaceted

Gell-Mann's interests extend beyond physics – he loves words, history and nature. He has moved between disciplines that include historical linguistics, archaeology, natural history and the psychology of creative thinking, as well as other subjects connected with biological and cultural evolution and with learning. He currently spearheads the Evolution of Human Languages Program at the Santa Fe Institute, which he co-founded.

The subsequent talks by Nicholas Samios of Brookhaven National Laboratory and George Zweig of Massachusetts Institute of Technology (MIT) were very entertaining. They touched on the historical background that led

to the discovery of the Ω^- – predicted by Gell-Mann's Eightfold Way – and to the quark model of hadrons, and were accompanied by interesting anecdotes and photographs. Zweig related the origin of the terminology "quark" and how the battle between "aces" and quarks unfolded.

There were several talks on recent advances in various theoretical and experimental aspects of QCD as well as on the Higgs boson. CERN's John Ellis discussed the Higgs particle and prospects for new physics at the LHC. Nobel laureate C N Yang of Tsinghua University gave a talk on his recent work on the ground-state energy of a large one-dimensional spin-1/2 fermion system in a harmonic trap with a repulsive delta-function interaction, based on the Thomas-Fermi method. Gerard 't Hooft of Utrecht University – another ▷

CELEBRATION

Nobel laureate – presented a possible mathematical relationship between cellular automata and quantum-field theories. This may provide a new way to interpret the origin of quantum mechanics, and hence a new approach to the gravitational force.

Gell-Mann himself ended the first day's sessions with interesting personal recollections and reflections on "Some Lessons from 60 Years of Theorizing". His main observations can be summarized as follows. First, every once in a while, it is necessary to challenge some widely conceived idea, typically a prohibition of thinking in a particular way – a prohibition that turns out to have no real justification but holds up progress in understanding. It is important to identify such roadblocks and get round them. Second, it is sometimes necessary to distinguish ideas that are relevant for today's problems from ones that pertain to deeper problems of the future. Trying to bring the latter into today's work can cause difficulties. Finally, doubts, hesitation and messiness seem to be inevitable in the course of theoretical work (and experiments too, sometimes). Perhaps it is best to embrace this tendency rather than organizing over and around it, for example, by publishing alternative contradictory ideas together with their consequences, and leaving the choice between them until a later time.

The following day and a half covered a variety of topics. Rabindra Mohapatra of the University of Maryland discussed neutrino masses and the grand unification of flavour. Further talks focused on the origins of neutrino mixing and oscillations, as well as on what the LHC might reveal about the origin of neutrino mass.

John Schwarz of Caltech gave an interesting review of the recent progress in the correspondence between anti-de Sitter space and conformal field theory, which is one of the most active areas of modern research in string theory. He focused mainly on the testing and understanding of the duality and the construction and exploration of the string theory duals of QCD. Other talks reported on string phenomenology and string corrections in QCD at LHC. Itzhak Bars of the University of Southern California described a gauge symmetry in phase space and the consequences for physics and space-time.

The sessions on quantum cosmology covered topics on black holes, dark matter, dark energy and the cosmological constant. These included a talk by Georgi Dvali of New York University, who discussed the physics of micro black holes.

The main sessions of the conference ended with a talk by Nobel laureate Kenneth Wilson of Ohio State University, a former student of Gell-Mann. He touched on a fundamental problem: could the testing of physics ever be complete? According to Wilson, in the real world no law about continuum quantities such as time, distance and energy can be established to be exact through experimental tests. Such tests cannot be carried out today, and cannot be done in the foreseeable future – although estimates of uncertainties can be improved in future. Wilson also took part in a discussion session with school teachers and students in a Physics Education Meeting held in conjunction with the conference.

The parallel sessions on particle physics, cosmology and general relativity attracted presentations by more than 30 speakers, many of whom were young physicists from Asia (China, China (Taiwan), India, Indonesia, Iran, Japan, Malaysia and Singapore). There was also a special session on quantum mechanics and complexity featuring invited speaker Kerson Huang of MIT who gave a talk on stages of protein folding and universal exponents.



Participants gathered in the foyer of Nanyang Executive Centre in Nanyang Technological University (NTU) with Gell-Mann (front row, seventh from the left). (Courtesy Institute of Advanced Studies, NTU.)



Murray Gell-Mann (left), Feng Da Hsuan (centre) and Gerard 't Hooft engaged in some light discussions during a tea break. (Courtesy Institute of Advanced Studies, NTU.)

● To mark the occasion of Gell-Mann's 80th birthday, the publication of *Murray Gell-Mann: Selected Papers*, edited by Harald Fritzsch (World Scientific 2010), was launched during the conference.

For the full list of speakers and more information about the conference, see www.ntu.edu.sg/ias/upcomingevents/GM80Conference/. The proceedings will be published by World Scientific Publishing Company, Singapore.

Résumé

Gell-Mann : mécanique quantique et complexité

Pour célébrer, à l'occasion de son 80^e anniversaire, les nombreuses contributions de Murray Gell-Mann à la physique, l'Institut de recherche avancée de l'Université technologique de Nanyang et l'Institut Santa Fe ont organisé conjointement une conférence en son honneur, qui a eu lieu à Singapour du 24 au 26 février. Sur le thème « Mécanique quantique, particules élémentaires, cosmologie quantique et complexité », pour souligner les apports de Gell-Mann dans ces domaines, cette conférence de trois jours a été l'occasion de communications et d'échanges variés. Elle a rassemblé plus de 150 participants issus de 22 pays, dont d'anciens étudiants et collaborateurs de Gell-Mann et plusieurs prix Nobel.