

## The Royal Society – Fri 04, Mar. 2011 1 pm-2 pm – Dr. Graham Farmelo

Link for access: <https://youtu.be/jPwo1XsKKXg>

About Farmelo:

- Science museum.
- Fellowship in Cambridge.
- Institute for advanced studies in Preston.
- Full time writer.

Notes on Dirac:

- Most illustrious scientist of the 20<sup>th</sup> century.
- The theoretician's theoretician, the first true modern physicist.
- C P Snow: "Greatest English man"
- Obsessed by mathematical beauty – If Math Beaut it is a candidate for a fundamental theorem.
- Oppenheimer: "Dirac is algebraic, not geometric", Dirac disagreed.
- Farmelo: "Every Physicist has to know at least one story about Dirac as a right of passage".
- Bohr: "Strangest man in QM. Private, few words, rectilinear in thinking, no empathy, an outsider".
- He loved climbing trees during lunch.
- Anti philosophical, anti religion.
- Pauli: "There is no god, and Dirac is his prophet".
- Extreme taciturnity.
- Dirac 1907:
  - Father Switzerland (fled unhappy childhood)
  - Mother Cowart
  - Felix brother
  - Betty sister
- Dirac: "I never had a childhood"
  - No visitors
  - Driven to always study
  - Linguistic regime during dinner: Men in the front room – only French –, women in the kitchen – only English. He told a reporter in 1930's that he thought that men spoke French and women spoke English.
  - He saw every meal as a trial. His father would only speak in French to his children and punished any error by denying his kids next week.
  - Dirac had stomach ache – denied by poor French.
- Dirac admits he had a superb education.
- He was very quiet and would only talk if the professor made an error, his hand would shoot up.
- Among the children he spoke to, Carry Grant lived 100 yards up the road. Both had a great education in technical drawing.
- Farmelo thinks that his drawing was when he was first introduced to geometric thinking.

- 1851's great exhibition caused the school syllabus to change by Sir Henry Coal – inventor of Christmas card, first director of the VNA, etc. – who was brought in from inland to change the school syllabus for boys, but not girls 😞 they still got to learn to cook and clean – big sad.
- Dirac studied technical drawing for 9 years.
- He was not a genius at school but was crushing it.
- 1914, after the opening of the WW1, he went to another superb school, one of the most well publicly funded in the country, the merchant venturer's technical college.
- The best prof at the school was Charles Dirac – his daddy – Dirac learned a new language every summer.
- Two years in he took off, his teachers didn't know what to do. His math teacher gave him a textbook in Romanian Geometry.
- Dirac: "At 13 I used to get home and ponder about space and time".
- Felix was smart but not Dirac boy.
- His father bullied Felix into not being a doctor and forced him to be an engineer. He struggled, and Dirac gave him a hand by doing a degree in engineering at merchant venture's technical college with his bro – what a sweetheart.
- Dirac hated experiments and sucked at them.
- During undergrad, he visited factories, built model airplanes, built cars, learned how to fill tax forms – very practical.
- Royal astronomical society decided to make Einstein a global superstar. Newton vs. Einstein on the eclipse results at the time (Einstein won). Became person of the century. That was when Dirac fell in love with theoretical physics – science began in 1950's in the heart of Germany.
- First rate engineer! But sucked at writing a report at a placement in rugby at an engineering works. "You are a very bright guy, but don't please get a job at a factory".
- Him and his bro had a fall out, no one knows why. They did not talk.
- 1921 Paul Dirac was the most successful graduate, but no jobs to be seen – economic recession.
- His instructor in an electrical engineering lab, David Roberts, saw Dirac was doing really bad in his experiment and said, "You don't want to do that" and got him into a math degree.
- Dirac finished his math degree in two years.
- Dirac met "The best teacher [He] ever had", Peter Fraser, who never published a single paper and devoted his life to teaching. He was obsessed with mathematical beauty and taught projective geometry – Lines and Planes with very little equations. Uses a lot of technical drawing!
- His father pushed him to get Dirac into Cambridge into a PhD in 1923 (after 21<sup>st</sup> birthday) St Johns' college. Talent-scouted him from Bristol.
- Supervisor was Ralph Fowler (Good handshake), Dirac wanted to study relativity but was put to study to QM.
- His math and engr degrees were not recognize by Cambridge but did great in the scholarship tests.
- March 1925 he was doing great, 5 papers, ready to get his PhD. But on March 8<sup>th</sup>, 1925, he got a letter from his aunt Nell saying his bro killed himself 😞. He never talked about it, and was so traumatized, he never showed his brother's pics to his children. His productivity plumbed.

- Summer 1995, he went to visit his family, his supervisor sent him a copy of the first paper in QM. It was the proof of Heisenberg's paper in QM. Not a masterpiece then. Dirac looked at it and said, "Nature can't be this complicated" and put it aside.
- Heisenberg's paper said that if you represent variables, not as numbers, but as matrices, the order in which you multiply them matters. Momentum times position is not the same as position times momentum but didn't quite know yet. Which Dirac had seen that in his studies of projective geometry, and from Heisenberg's work, he wrote the fundamental equations of QM – his first great paper, which still reads as a modern paper.
- Dirac showed how the matrix interpretation of Heisenberg and the wave interpretation of Schrödinger were the same. He called that paper my darling!
- He then co-invented field-theory.
- Dirac did a calculation on the interaction between a photon and an electron, and found he got infinity for the Energy of that system. He said "This is obviously wrong, but we can get rid of this". This troubled him for the rest of his life.
- He was still not a mighty figure in physics, until late 1927. He combined QM with special rel to make the Dirac equation! Frank Wilczek said it was "achingly beautiful". He made his hero proud (Einstein).
- Dirac's equation described the electron in the way he wanted but explained the recently observed phenomenon of electron spin and why electrons have magnetism.
- He was the star of the year 1928, the leading master of QM.
- Heisenberg said: "There is this English guy, if he tackles a problem, it's not worth going anywhere near, frankly. Because he is so smart. It's just not worth it competing with him."
- He used the equation to predict the existence of the positron. Identical mass of the electron but with the exact opposite of the charge. It was seen as a joke, too wild
- August 2<sup>nd</sup>, 1932, during the LA Olympics. The first positron was detected at the California institute of technology – 7 months after Dirac predicted!
- Heisenberg said it was probably the biggest of all steps taken in the 20<sup>th</sup> century physics was to open this world of anti matter. Which he found from mathematical thinking! Holy shit.
- He wrote some experimental physics in Rutherford's lab.
- Already have a Nobel Prize.
- 250,000.00 pounds a year.
- He wanted love! October 1<sup>st</sup>, 1934, he met "Wigner's sister".
- She was once furious at him and sent him a letter asking why you don't answer any of my questions, and he sent back a table with an enumerated list of letters with unanswered questions and their answers.
- She called him "my little mickey mouse" because it was his favourite character.
- 2 children.
- He worked on his neutron flux calculations for a nuclear bomb in his back garden.
- He had studied QM so much, he started to strongly dislike it.
- He was invited by Max Born to the university of Edinburgh to give a talk on the philosophical aspects of physics in Feb 1939 (which he surprisingly accepted). He called it "The relations between mathematics and physics" and it had no Math in it.

- From talk: “Mathematics is a game where mathematicians invent the rules. Physics is a game where the rules are given to us by nature. What is interesting is that the rules of nature appear to be in the same in mathematical rules as the mathematicians have concocted.”
- He introduced the principle of mathematical beauty. Physics advancements were given by beautiful theories, but he detested his quantum-field theory since it was “so dammed ugly”, and felt offended by it.
- After WW1, “QFT was tided up” by Richard Feynmen, as he said it. It made so that the observables of electrons and photons could be taken such that you could just remove the infinities away making them not part of the calculation. Dirac called it an “Abomination”, but it worked.
- “What do you think about the theory of quantum electrodynamics, Dirac?” Feynmen;  
“ I would like it if it wasn’t so ugly” Dirac.
- “Beauty was like a religion”, Dirac.
- He wrote a popular article on the history of theoretical physics, but focusing on the beauty of theoretical physics.
- “it is more important to have beauty in one’s equations than to have them agree with experiment”, Dirac.
- “God appears to be a mathematician of very high order”, Dirac.
- In 1970s, Heisenberg sent Dirac his latest theory. Dirac replied in one line “Dear Heisenberg, thank you for sending me your new theory, it is so ugly the equations can’t probably be right”. Heisenberg replied basically saying “Paul, c’m on” and Dirac replied with “I am very serious – it makes no sense to deal with a theory this ugly.”.
- 1969 his Cambridge position as a Lucasian Chair in Cambridge was up, so he moved to the physics department ranked 83<sup>rd</sup> in America (Florida state university).
- He became the apostle of mathematical beauty with 600 talks all over the world about it.
- He became a better human being, went to more popular events, classical presentations, and he bought a television to watch to Cher and Elton John.
- At 80 years old, he felt disillusioned, because people made fun of him for rejecting his own creation (Field Theory).
- Last visited Britain in 1982, he received a letter from Feynmen’s supervisor saying “I write to tell you that I’m not sure you divine how many of the younger generation as well as the older one looks up to you as a hero, as a model of how to do things right, of a passion for rectitude of what is beauty. May your influence keep on growing”.
- Edward Witten met with Dirac, where Dirac complained about QF theory. He advised Witten to move away from it. Days after he died.
- His last words in his death bed were about the abomination QFT is.
- He was buried in Roselawn, Tallahassee with his wife and a statue of his dog.
- He never claimed to invent QFT all by himself, but the more he tried to prove it wrong the more right it looked.
- He began anti religious and anti philosophy, and ended his life studying beauty as a religious philosopher.