

Albert Einstein: Relatively Speaking

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This is an edited and slightly expanded version of a talk given at the public meeting “A Century of Gravity Theory” on 26th November 2015. It was accompanied by a PowerPoint presentation, some of whose images are included here. Two further talks followed: “Einstein’s Theory simply explained” by Professor Graham Hall and “Experimental Tests of General Relativity” by Teodora Oniga.

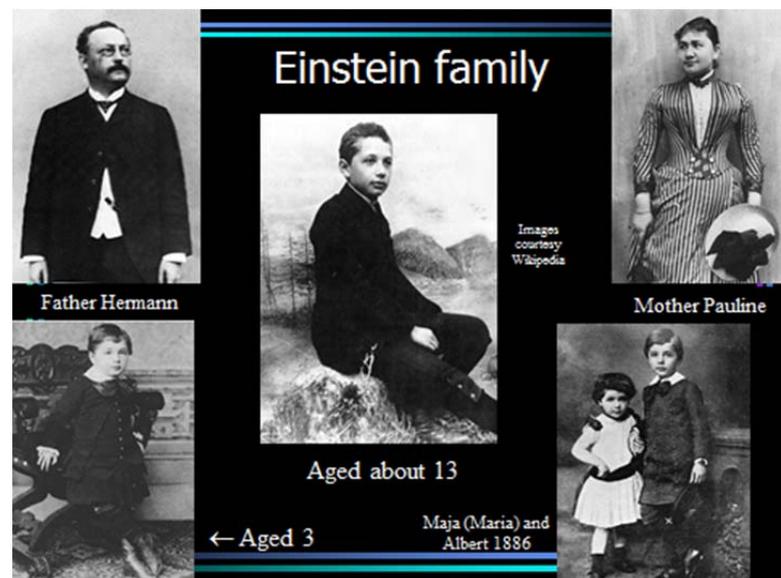
Abstract

Einstein made fundamental contributions to optics, solid state physics, molecular physics and quantum mechanics but it was his theories of relativity that made him the most famous scientist in the world. Einstein had an extraordinary life. This talk will look at the man behind ‘relativity’ and in particular the years during which he developed his ideas.

Introduction

A century on from his most far reaching work, Einstein is still an iconic figure. He was *Time Magazine*’s ‘person of the century’ in their issue of 31st December 1999 (beating even Elvis Presley); he has been widely quoted, widely parodied. His image has appeared on numerous front covers, on perhaps 100 postage stamps of the world from many countries, in probably tens of thousands of cartoons and on millions of T-shirts. ‘Albert Einstein’ brings up many more Google hits than ‘Isaac Newton’ or even ‘Charles Darwin’. Was he a genius from a young age, or just an ordinary bloke who had extra-ordinary ideas?

Einstein was born 136 years ago, on 14th March 1879 at 135 Station Road (Bahnhofstraße B 135), Ulm, in southern Germany. [The building was destroyed in



the Second World War]. His parents were non-conformist Jews who didn't practice most of the Jewish rituals. They even called their children Albert and Maria, not traditional Jewish names. (Images on the slide are courtesy Wiki Commons). A year later the family moved about 200 km East to Munich, where his father Hermann Einstein and uncle Jakob set up a supply firm that began as a provider of gas and water installations but transformed itself into an electro-technical manufacturer (dynamos, switches, etc.). It was only a modest success. It would get custom all over the world today but Einstein's name was nothing special then.

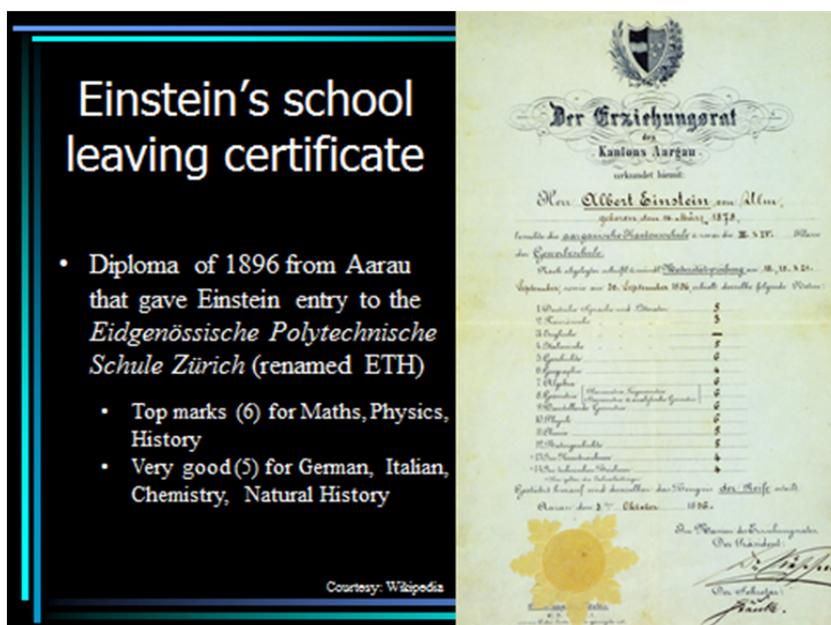


Contemporary map showing Einstein's places of residence that will be mentioned.

At secondary school in Munich, the gymnasium, Einstein was not a happy pupil. He abhorred the rote learning and the discipline that German culture had elevated to a national obsession. Albert was quiet, wanted to learn by himself, scored reasonably well in exams but not brilliantly. When his father asked the headmaster what career his son should take up, the reply was apparently "it doesn't matter, he'll never make a success of anything". When he was 15 years old, his parents and sister moved to northern Italy after the electro-technical business had failed and they left Albert behind in Munich to finish his schooling and obtain

his leaving certificate. He didn't. Accounts vary but it seems that six months later he tried to obtain medical exemption to leave school but was expelled, as the citation said *'because your presence in this class is disruptive and affects the other students'*. He did what many a high-school drop-out with no job might have done – he went home.

Unlike many drop-outs, he studied on his own and in due course he sat the entrance exam for the Swiss Federal Polytechnic School in Zürich. He failed to get in, though apparently this was mainly due to his poor French. He went to school for a year in Aarau in Switzerland, an experience he enjoyed in contrast to the Munich gymnasium, and he left in 1896 with their



matriculation diploma that gave him entrance at last into the polytechnic. At that time it was the *Eidgenössische Polytechnische Schule Zürich* but early in the 20th century was rebranded as the *Eidgenössische Technische Hochschule Zürich*, which today as ETH Zurich is one of the top 10 Universities in the world rankings. In 1896 he also renounced his German citizenship, with his father's sanction.

At the polytechnic he acquired something of a reputation for skipping classes and studying on his own. Four years later he graduated with 3 others, with good marks in physics, astronomy and mathematical analysis. No-one recorded seeing any signs of genius. Indeed, his fellow 3 graduates were all offered Assistant posts at the *Schule* but Einstein wasn't. Einstein didn't like the experience of the final exam. He said later *One had to cram all this stuff into one's mind for the examination, whether one liked it or not. This coercion had such a deterring effect on me that, after I had passed that final examination, I found the consideration of scientific problems distasteful for me for an entire year.* On another occasion he said that *"the wit was not wrong who said that Education is what remains if one has forgotten everything one learned in school"*. We're now in the year 1900 in our story.



Einstein at 17

In 1901 Einstein was sworn in as a Swiss citizen, having been stateless for several years. After presenting himself for the compulsory few-month Swiss national service he was shocked to be refused, on account of his flat feet and varicose veins. He got temporary jobs as a teacher and during one job he wrote what he hoped would be a doctoral dissertation on

the kinetic theory of gases, which he submitted to the ETH. It was not accepted. Finally he secured a job in the Patent Office in Bern on June 16th 1902, albeit on probation. His job was not secure until over 2 years later. He had fallen in love with his former class-mate in Zürich, Serbian physics student Mileva Marić who had failed her final exams. In January 1902 she gave birth to an illegitimate daughter by him.

He's now 23, a lad with a modest educational record, a modest means, a modest job and an illegitimate daughter. Not even the most reckless gambler would put money on this man becoming 'person of the century'. He seemed to be like a thousand others at the time. Would anyone have given him a research grant, had there been such things? Possibly not. Einstein never applied. He had applied for University jobs and failed to excite any interest. He married Mileva the following year and they had their first son, Hans Albert in 1904. Many years later Hans Albert would become a well-known Professor of Hydraulic Engineering in Berkeley, California.



Mileva and Albert

<http://www.teslasociety.com/Mileva.htm>

When you read about his life until then it sounds exactly the kind of biography you might read of a patent clerk (3rd class, as he was). For past-times he enjoyed sailing on Switzerland's lakes as a relaxation and likewise musical evenings in which he played the violin. What I have clearly missed out of the story so far is Einstein's passionate interest in Physics in general and in particular fundamental questions that were taxing physicists at the time. There were flickers of evidence until the year 1905, when Einstein as a clerk in the Patent Office sent his first paper of the year to the prestigious publication *Annalen der Physik* in March. It was on the light quantum and the photoelectric effect, and urban myth says that he asked if it could be published 'if they had room'. This was the paper that was particularly mentioned in Einstein's Nobel Prize citation in 1921. In April he completed a new doctoral dissertation, not on light but 'On a new determination of molecular dimensions'. ETH Zürich accepted it in July. In May he submitted his groundbreaking paper on Brownian motion that became the most quoted physics paper of the year. In June he submitted the first of two papers setting down the fundamentals of the theory of Special Relativity; in September a second paper on Special Relativity followed, giving his even more famous equation $E =$

ANNALEN
DER
PHYSIK.

PAUL BREUER

Patent Office

Einstein in 1905, his *annus mirabilis*

- Also obtained PhD from ETH Zurich

Gibt ein Körper die Energie L in Form von Strahlung ab, so verkleinert sich seine Masse um L/c^2 .

The first appearance of $E = mc^2$

mc^2 [actually, $m = L/v^2$ “Gibt ein Körper die Energie L in Form von Strahlung ab, so verkleinert sich seine Masse um L/v^2 ” - *A body loses energy L in the form of radiation, so its mass reduces by L/v^2*]. In December he submitted a second paper on Brownian motion. These papers changed physics across the world. Where did they come from? Probably from a good ten years of thinking intensely about physics and forming his own ideas, with an intuitive grasp of what was right and what wasn't. When he was asked much later how long it took him to conceive of Special Relativity he said ‘*The idea came to me quite quickly but I have been thinking about it all my life.*’

Einstein himself admitted he was a late developer. He said to his friend James Franck that most adults don't worry about space and time because they have sorted out what's what in childhood. But, said Einstein, “*my intellectual development was retarded, as a result of which I began to wonder about space and time only when I had already grown up*”. That's well documented. One trouble with Einstein stories is that they get repeated regardless of their veracity, so a mythology has built up. He was said to be a late talker as child, not saying anything until he was three and half. Suddenly he said “*the milk is too hot*”. His mother was amazed. “*You can talk!*” she said, “*why have you never spoken before?*” Legend has it that he replied “*Because previously everything was in order.*” Likely story!

Einstein soldiered on in the Bern Patent Office, thinking about physics at home while rocking young Hans Albert in his cradle. His illegitimate daughter had been taken to Serbia for adoption and may have died only 1 year old. Special Relativity is all about physical systems moving at constant velocity relative to each other. It interested a few in physics, some of whom corresponded with him while a few others came to visit him. In November 1907 he had ‘*the happiest thought of my life*’ [*glücklichste gedanke meines lebens*, as he put it]. “*I was sitting in a chair in the patent office at Bern when all of a sudden a thought occurred to me. If a person falls freely he will not feel his own weight. I was startled. This simple thought made a deep impression on me. It impelled me toward a theory of gravitation*”. This was the Einsteinian moment akin to Newton under the apple tree realising the significance of the falling apple. Einstein went on to formalise the idea of the ‘Equivalence Principle’, which is one of the foundations of General Relativity. Einstein saw General Relativity as first and foremost a theory of gravity. Through the equivalence principle it becomes a theory in which Special Relativity is extended to accelerating systems. Graham Hall will say more on this.



University of Bern

In 1907, with some professorial support and his doctorate from Zürich, Einstein applied to become

a ‘privatdozent’ at the University of Bern. The post was part-time but a precursor to

becoming a professor. His application was rejected, possibly on a technicality. In early 1908 the decision was reversed and in the summer of 1908 he began his formal academic career, giving his first lecture course to 3 students. At the following winter course, 4 students attended. After some time, only 1 remained. Not exactly a great result for someone who had graduated as a ‘specialist teacher’ [Fachlehrer] from Zürich.

At age 30, though, his luck began to change. Hermann Minkowski at Göttingen had shown that Special Relativity could be elegantly formulated mathematically in terms of a unified ‘space-time’ continuum, an idea that gave it theoretical physics credibility. Minkowski had been Einstein’s maths teacher at ETH Zürich, describing him as ‘a lazy dog’ who ‘never bothered about mathematics at all’. It was Minkowski who was a big factor in making the bark of the lazy dog more widely heard. Sadly, Minkowski died of peritonitis early in 1909. Thanks in part to Minkowski’s development, by the end of 1909 Einstein had been awarded an honorary doctorate in Geneva and had accepted the post of Assistant Professor of Theoretical Physics at the University of Zürich: more sailing on the Zürichsee, and also more opportunity for his idea of developing Special Relativity into something more general. He was a patent clerk no more.



*Hermann Minkowski courtesy
Wiki Commons*

Einstein enjoyed Zürich. He found his own lecturing style, and his students found him more approachable than the traditional lecturer. At times he was lecturing 6 – 8 hours a week. I suspect it was in his Zürich days that the following anecdote originated. There is a story that one of his students came up to him and said “*Professor, the questions in this year’s exam are the same as in last year’s exam*”. “*True*”, said Einstein, “*but this year’s answers are all different.*” Was the new lecturer bringing the coursework up-to-date? He liked Switzerland in general and the way the place worked in particular. He seemed happy and relaxed. In a 1911 paper he showed that there should be two effects from gravity interacting with light. The first was a bending of light passing near a large mass; the second a red-shift of spectral lines originating in a gravitational field.



Zürich University

The Zürich Faculty were surprised and amazed when Einstein announced in 1911 that he was accepting a post as full Professor in the German University of Prague. For this he had to take Austro-Hungarian nationality, against his will, for it was a civil service appointment. Prague was a fine historic city; it had been the city where Tycho Brahe met Johannes Kepler, some 3 centuries earlier; Ernst Mach had been the first Rector of the German University. As one

biographer has commented, Einstein's home in Bern had been lit by oil lamps; in Zürich by gas but in Prague by electricity, and the Einsteins had a live-in maid, help to look after their two sons, for Eduard Einstein had been born in Zürich in 1910. The Prague post was also short-lived but in the General Relativity story was important for it was here that he was introduced by the mathematician Georg Pick to the tensor calculus that he found he would need to formulate his General Relativity. He also met Paul Ehrenfest there with whom he established a strong friendship.

In life's game of snakes and ladders, Einstein was now climbing the ladders rather quickly. He received offers of Professorships from several Universities. In August 1912 he moved back to Zürich as a full Professor, not at the University but at ETH Zürich, his alma mater. Zürich was a city both he and Mileva felt more at home in, not only because of the sailing on the Zürichsee.

As an aside, relativity, both special and general, was not dreamt up by an elderly, eccentric scientist with flying white hair and a dislike of wearing socks but by a civil servant and later a more or less conventionally dressed academic whose normally rumpled suit and baggy trousers you would pass on campus without a second look.

The pre-war years in general were characterised by almost as much mobility of scientists as you find today – not so much scientists changing jobs every year or two as Einstein did but in travelling abroad to meetings and special conferences. Einstein was now meeting the big names in person in The Netherlands, in Belgium, in France, in Austria, in Germany, and giving talks about Relativity in particular. Max von Laue, Madame Curie and her daughters, Max Planck, Walter Nernst, amongst others, came to visit him in Zürich. In Physics circles he was now a leading light.

[While in Prague he had corresponded with Erwin Freundlich from the Berlin Observatory, the first astronomer to consider astronomical tests of the interaction of gravity with light. Freundlich was an interesting character with a Scottish mother (née Finlayson) who, in the 1950s, would become Professor of Astronomy at St Andrews and rebadge himself as Finlay-Freundlich. He met Einstein at last in Zürich, while on his honeymoon no less which was disrupted by lengthy discussion with Einstein on the possibility of measuring the apparent displacement of stars whose light had passed close to the Sun. Freundlich went on to obtain copies of photographs of the Sun during an eclipse with stars in the background, taken years earlier by American astronomers searching for a postulated planet Vulcan orbiting near the Sun that might account for anomalies in Mercury's orbit. It would turn out these photographs weren't up to the task of testing Einstein's ideas. The Freundlichs became good friends of the Einsteins and with Einstein's support Erwin organised an observing expedition into the



Einstein in 1912: Similar to <https://www.phys.ethz.ch/the-department/history.html>

Crimea for the next eclipse that would take place on 21st August 1914. Scientists have a good track record of ignoring political tension between nations but WWI was a step too much to ignore. Germany declared war on Russia on 1st August. The expedition equipment was already set up. It was seized by the Russians and the German astronomers were arrested. No results were obtained, nor in fact would have been obtained for the American and Cambridge astronomers who were also there experienced the total phase of eclipse clouded out. This failure left the door open for the important events that Teodora will pick up in the third talk].

By the time of these events in 1914, Einstein had made yet another move. He had been lured to Berlin in April 1914 where he'd been offered an even bigger salary, a post as Director of the about to be established physics wing of the Kaiser Wilhelm Gesellschaft (that after WWII would become the Max Planck Institute), simultaneously a post as a Professor in the prestigious Prussian Academy of Sciences with a supplementary Professorship in the University of Berlin and, what really mattered, freedom to pursue his own research with minimum hindrance. He said to a colleague in Zürich "*The gentlemen in Berlin are gambling on me as if I were a prize hen. As for myself, I don't even know whether I'm going to lay another egg*".

The egg he had been gestating for years by then was General Relativity. Berlin would see the culmination of his efforts to produce a coherent, mathematically formulated, theory. The gamble of the 'gentlemen in Berlin' would pay off. It would, though, be a step too far for Mileva, who moved back to Zürich with their sons in the summer of 1914 and never returned. Einstein would send her more than half his Berlin salary (and later gave her his Nobel Prize money). His divorce was legalised in 1919 and he re-married three and a half months later. Berlin and the war in particular would re-kindled his anti-German feelings that had caused him to renounce his nationality when a teenager; it would strengthen his pacifism and his socialist ideals.

Einstein layed his egg in 1915. He gave his first public talk on General Relativity at the Archenhold Observatory in Berlin, an event now commemorated by a plaque on their lecture-room door. In November he gave weekly highly technical lectures at the Prussian Academy of Sciences, more or less as he put the finishing touches on his ideas. The formulation he gave in his final lecture on 28 November was described by the physicist Max Born, who had also been lured to Berlin, as "*the greatest feat of human thinking about nature, the most amazing combination of philosophical penetration, physical intuition and mathematical skill. But its connections with experience were slender. It appealed to me like a great work of art*".



Archenhold Observatory
plaque: photo JSR

One story related by Alexander Moszkowski, a fellow member of the Prussian Academy of Sciences, who was having coffee with Einstein when

one of the literary members of the Academy who had been reading Einstein's reports approached their table and said to Einstein "*Professor, will you kindly tell me the meaning of potential, invariant, contra-variant, energy-tensor, scalar, relativity-postulate, hyper-Euclidean, and inertial system? Can you explain them to me in a few words?*" "Certainly", said Einstein, "*they are merely technical expressions.*" And that was the end of the lesson. Actually I'm reminded of the dictum attributed to Ernest Rutherford who said "*an alleged scientific discovery has no merit unless it can be explained to a barmaid*". Even today, when he may well find a barmaid with a PhD, Graham Hall will be doing well to pass Rutherford's test.

At the end of the first world war Einstein was very well known in Physics circles but almost unknown by the public, even in Germany. General Relativity brought Einstein the celebrity that he never really wanted. As has been said by others, he was seen as the messenger of the new order. Light has weight, the universe has 4 dimensions, space-time is warped. People loved it. They didn't really know what it meant but a few eminent disciples did and they saw that it was good. Einstein might not have been quite the messiah of science, but he was the next best thing. Like many famous people since, he viewed his popularity as a very mixed blessing. He once said ruefully "*To punish me for my contempt for authority, fate made me an authority myself*".

In the 8 years from 1907, and in particular from 1911 to 1915 he had been a driven academic, driven by the thought that in Special Relativity he had an incomplete idea that he desperately wanted to see to completed. Privacy to think was what he cherished. Not a lot else mattered. He lost his family and at times his health. Post war he became public Einstein, highly respected for his moral honesty, his humanity, and when it mattered his continued common sense when all about were losing theirs. He had thrust upon him the image of the public personification of a scientific genius which he and his second wife, his cousin Elsa Löwenthal, had to live with. As he once said "*Frau Einstein is there to protect me*". This is just a hint of his life after General Relativity was given to the world.

In spite of all his connections and influence, Einstein was, in his own words, a bit of a *lone traveller*. While he was developing General Relativity he was as socially self-sufficient as he could be. Had Twitter and Facebook been around he'd have had nothing to do with either of them. He valued his imagination as much as any formal training in science. On several occasions he said words similar to these: *I am enough of an artist to draw freely upon my imagination. Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world.* He was asked at one time where his laboratory was. He pulled a fountain pen from his pocket and said "*here*".

I think Einstein viewed general relativity in the same light as mathematicians view subjects like geometry, number theory, group theory and so on that start with postulates and build logically upon them. Einstein was sure of his postulates, and hence of his predictions. Ilse Rosenthal-Schneider was a PhD student in Berlin in 1919 and was with Einstein when the result of Eddington's eclipse observations arrived in a telegram sent by Lorentz. "*What if*

there had been no confirmation of your prediction?" she said. His answer was: "Then I would feel sorry for the good Lord. The theory is correct anyway."

For a physicist to say something like that would be arrogance; for a mathematician, quite natural. It wasn't mathematics, though, that really motivated Einstein. It was Philosophy: literally, the love of wisdom.

JSR

Footnote – some additional quotes

Einstein wrote in 1921 *"There are plenty of the well-endowed, thank God, and I'm firmly convinced that most of them live quiet, unobtrusive lives. It strikes me as unfair, and even in bad taste, to select a few of them for boundless admiration, attributing super-human powers of mind and character to them. This has been my fate, and the contrast between the popular estimate of my powers and achievements and the reality is simply grotesque"*. [from p 302 *Einstein, a Centenary Volume*, 1979] He underestimated his achievements but there is no doubt in his mind that he saw himself as a relatively ordinary bloke who had been lucky enough to think through some deep physical ideas.

Bertrand Russell on the radio: *"(Einstein) removed the mystery from gravitation."* ... *"I hope that an increasing proportion of philosophers will, as time goes on, become aware that ignorance of physics condemns any philosophy to futility"*. [Quoted in G. J. Whitrow, *Einstein, the Man and his Achievements*, 1967 p22]

In the conversations with Alexander Moszkowski, when Einstein was asked *"What if the expected experimental result does not appear? What if it contradicts the theory?"* He replied *"Such questions do not lie in my path. The result (of my theory) could not be otherwise than right. I don't doubt for one second that the result will agree with observation. There is no point in getting excited about what is self-evident."* [*Einstein the Searcher*, 1921]

Walking with a young woman physicist to his Berlin University office he commented that he had no interest in learning a new language, nor in food, nor in new clothes, *"I'm not much with people and I'm not a family man. I want my peace. I want to know how God created this world. I'm not interested in this or that phenomenon, in the spectrum of this or that element. I want to know His thoughts, the rest are details"*. [Ronald W. Clarke, *The life of Albert Einstein*, p33]

– and a technical answer

Someone at the end of the talks asked the question: *'what is space-time?'*

A useful answer to a deep question will take more than a sentence. With everyday concepts, those found in classical physics, time is time and space is space. Two separate events will have a time interval between them and a space interval. If two observers, call them Alice and Bob, are moving at a constant velocity relative to each other they will both measure the same

time interval between the events and obtain the same result for the distance between them. The situation seems so simple it's hardly worth making an issue out of it.

In relativity, Minkowski's space-time is intrinsically different. An interval between two events has a spatial and a temporal component. Alice can measure these components in her frame of reference. Bob, moving at constant velocity relative to Alice, will agree on the magnitude of the interval but sees the components differently. Part of what Alice sees as the temporal part of the interval now becomes a contribution to Bob's spatial component. Part of what Alice sees as the spatial component becomes a contribution to Bob's temporal component. The word space-time is intended to reflect the interdependent nature of space and time. It is a technicality that the concept of 'interval' is a bit different in Minkowski space-time from how it is applied in everyday life but in a way that just emphasises that space-time is a new concept. We live in Minkowski space-time, not in classical space and time. That was one of Einstein's big discoveries.