Where the Universe Came From

How Einstein's Relativity Unlocks the Past, Present and Future of the Cosmos

NEW SCIENTIST

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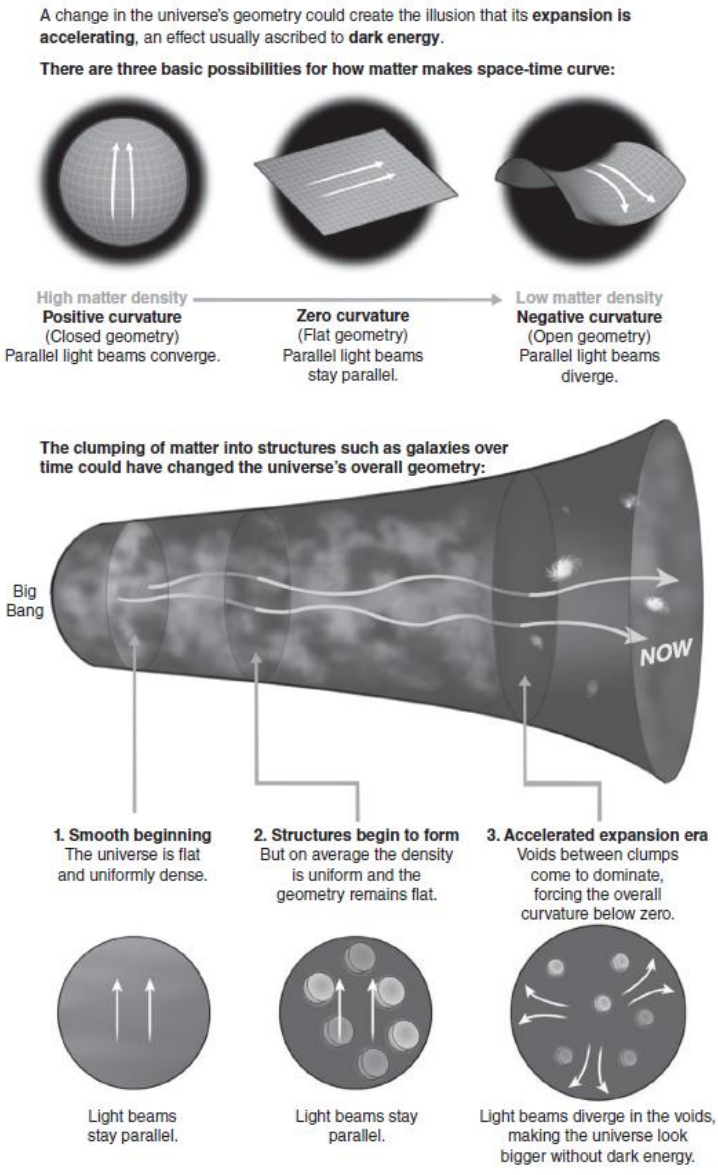
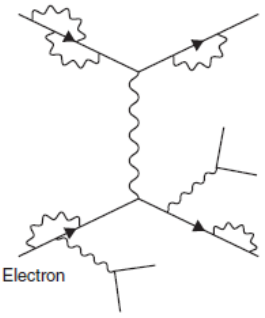
Finally, in November 1915 in his general theory of relativity, Einstein was able to describe how space-time gets curved by the presence of mass, energy and pressure:

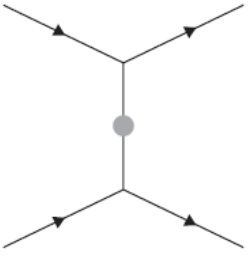
$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$



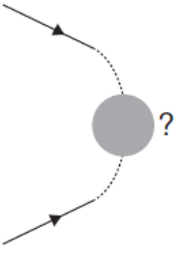
Bending space



Particles such as electrons can interact by producing and exchanging massless photons in countless ways, often resulting in infinities in the calculations.



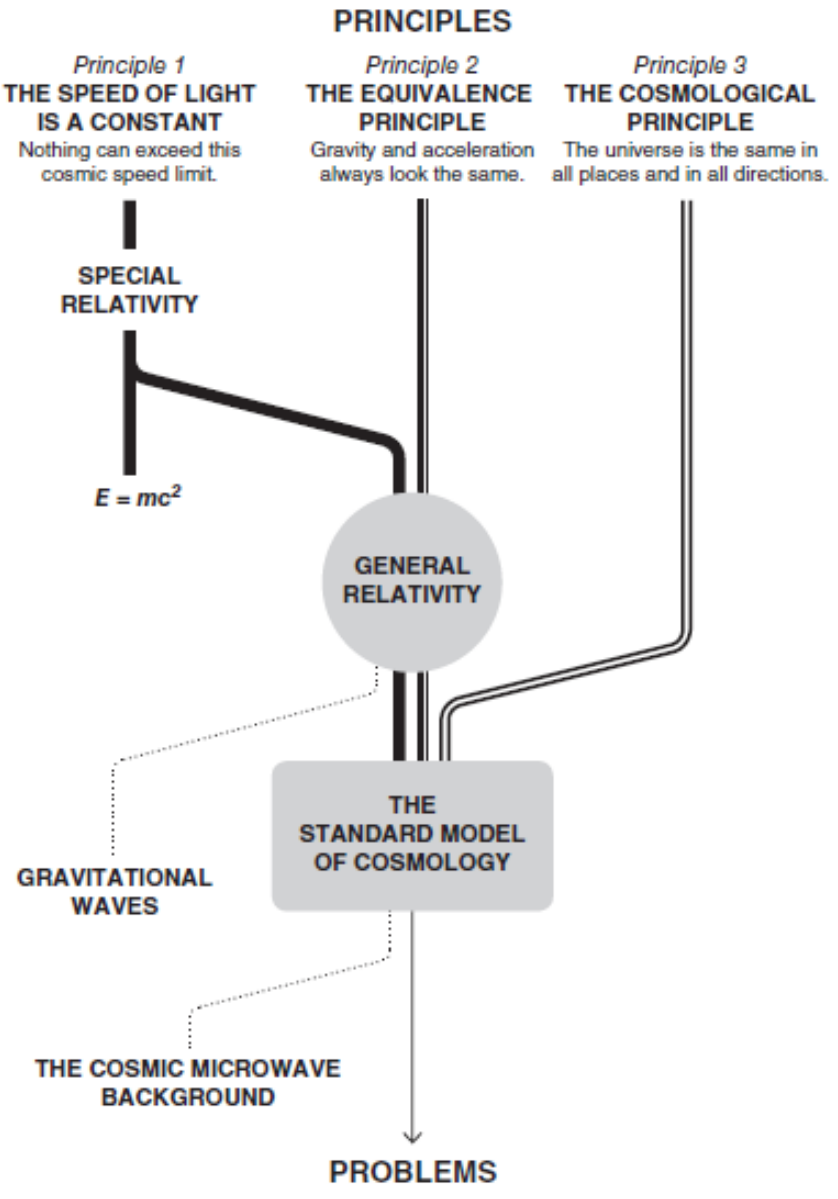
The situation is saved by the existence of heavier particles – the **W, Z and Higgs bosons** – that aren't so easily produced, cancelling out the infinities.



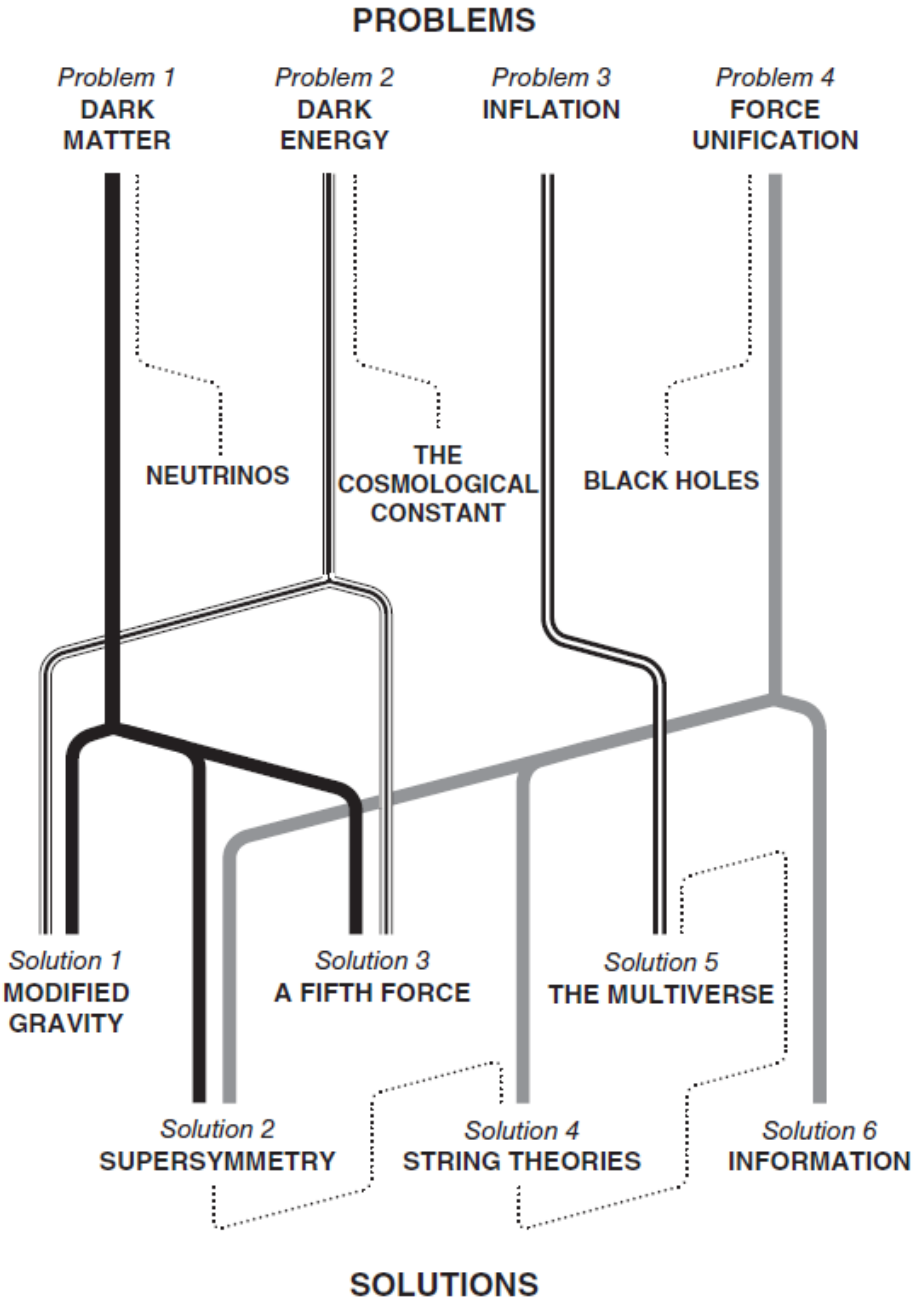
Graviton

Performing the same trick with graviton interactions requires a particle so massive it acts like a **black hole** – and all calculations are off again.

The infinite problem: gravitons are conjectured quantum particles of gravity, but theories incorporating them tend to be unruly



An outline of the principles, problems and solutions



An outline of the principles, problems and solutions

Fifty ideas

This section will help you to explore the subject in greater depth, with more than just the usual reading list.

Six spots for space-time tourism

1 **Ulm**, Germany: The house where Einstein was born is next to the railway station, the equations of relativity appear in a stained-glass window of the Lutheran church known as the Minster, and other monuments to the great man exist in this southern German city.

2 **Bern**, Switzerland: This is home to the patent office where Einstein served as Technical Assistant (level III) and the Einsteinhaus, a museum in the house where he and his family lived from 1903 to 1905.

3 While in **Switzerland**, you could seek out an Einstein-era train, the kind of vehicle that inspired his experiments involving light and clocks, leading to the disturbing conclusion that even Swiss trains can't be punctual to all observers. There's the Blonay-Chamby railway museum, for example.

4 **Príncipe**: On this tropical island off the west coast of Africa, Arthur Eddington made the first confirmation of the predictions of general relativity by observing the position of stars during a total eclipse.

5 **Washington DC**: In the grounds of the National Academy of Sciences you can visit the Albert Einstein Memorial statue, and even sit in his lap if you are so inclined.

6 **V616 Monocerotis**: If your budget stretches to an interstellar starship (and uploading your consciousness to its computer), then in a few millennia you could find out what really happens when space-time is stretched to breaking point by visiting the nearest known black hole, which is about 3,000 light years away.

Nine references to relativity in music, movies, literature and art

1 For that authentic 1980s-nerd-party feel, check out synthpop hit **'Einstein A Go Go'**, by British band Landscape.

2 More recently, Kelly Clarkson dazzled lyric lovers with the profound line 'dumb plus dumb equals you', in her song called simply **'Einstein'**.

3 The great mind has inspired some more highbrow music too. ***Einstein on the Beach***, an opera by Philip Glass, is named after a famous picture of … Einstein on the beach.

4 In ***Relativity Rag***, composer George Benjamin experiments with warping the familiar musical form in a way supposedly influenced by Einstein's theory.

5 The film ***Interstellar*** features an exceptionally realistic fake black hole, simulated by relativity expert Kip Thorne of the California Institute of Technology.

6 In the film and play ***Insignificance***, Einstein becomes entangled with Marilyn Monroe, Joe DiMaggio and Joseph McCarthy as they all meet in a Manhattan hotel room.

7 For a more serious attempt at portraying the man and his ideas, try the BBC drama-documentary ***Einstein and Eddington***.

8 Salvador Dalí's painting ***The Persistence of Memory*** shows the influence of relativity in its warped, melting watches.

9 M. C. Escher also inhaled the heady air of relativity for his student-hall-ubiquitous print that plays with gravity and space, ***Relativity*** (the one with the stairs; not the other one with the stairs).

Ten deep thoughts by Einstein

1 'The most incomprehensible thing about the world is that it is comprehensible.'

2 'If A is success in life, then A equals x plus y plus z. Work is x; y is play; and z is keeping your mouth shut.'

3 'According to the general theory of relativity, space is endowed with physical quantities; in this sense, therefore, an ether exists. Space without an ether is inconceivable.'

4 'Space has devoured ether and time; it seems to be on the point of swallowing up also the field and the corpuscles, so that it alone remains as the vehicle of reality.'

5 'What I'm really interested in is whether God could have made the world in a different way; that is, whether the necessity of logical simplicity leaves any freedom at all.'

6 '… 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.'

7 'Creating a new theory is not like destroying an old barn and erecting a skyscraper in its place. It is rather like climbing a mountain, gaining new and wider views, discovering unexpected connections between our starting point and its rich environment. But the point from which we started out still exists and can be seen, although it appears smaller and forms a tiny part of our broad view gained by the mastery of the obstacles on our adventurous way up.'

8 'All our science, measured against reality, is primitive and childlike – and yet it is the most precious thing we have.'

9 '… the distinction between past, present and future is an illusion, although a persistent one.'

10 'A man should look for what is, and not what he thinks should be.'

Eight anecdotes, jokes, facts and myths

(to be used in party conversation with appropriate caution)

1 It is a common myth that Einstein was a poor student. This idea may have emerged because the grading system at the time went up to 6, not 10. His matriculation certificate (http://rarehistoricalphotos.com/albert-einsteins-matriculation-certificate-1896/) shows that at the age of 17 he was getting good-to-excellent grades in everything … except French.

2 *There was a young lady named Bright,*
Whose speed was far faster than light.
She set out one day
In a relative way,
And returned home the previous night.

3 When early-adopter relativity expert Ludwig Silberstein approached Arthur Eddington at a party in 1919, he suggested that Eddington might be one of the three men who actually understood the general theory of relativity. Eddington was slow to reply. 'I was wondering who the third one might be', he eventually confessed, to a presumably downcast Silberstein.

4 Einstein loved a power nap, apparently.

5 A joke:

The barman says, 'Sorry, we don't serve hypothetical faster-than-light particles in here.'
A tachyon walks into a bar.

6 David Ben-Gurion offered Einstein the chance to be Israel's first President. He declined.

7 Despite perceptions that he was a kindly old gent, Einstein was capable of being quite belligerent, and even unreasonable. In July 1936 he replied to editors at the *Physical Review* (who had in the usual fashion sent his submitted paper out for peer review) in these words: 'Dear Sir, We (Mr Rosen and I) had sent you our manuscript for publication and had not authorized you to show it to specialists before it is printed. I see no reason to address the – in any case erroneous – comments of your anonymous expert. On the basis of this incident I prefer to publish the paper elsewhere.'

8 John Wheeler is often said to have coined the term 'black hole', but in fact he adopted it from an anonymous audience member at a talk in 1967: 'In my talk, I argued that we should consider the possibility that the centre of a pulsar is a gravitationally completely collapsed object. I remarked that one couldn't keep saying "gravitationally completely collapsed object" over and over. One needed a shorter descriptive phrase. "How about black hole?" asked someone in the audience. I had been searching for the right term for months, mulling it over in bed, in the bathtub, in my car, whenever I had quiet moments. Suddenly this name seemed exactly right.'

Eight people Einstein corresponded with

1 **Sigmund Freud**. In 1932 Einstein and the psychoanalyst corresponded about violence and war. Einstein wrote, 'Is it possible to control man's mental evolution so as to make him proof against the psychosis of hate and destructiveness?' Freud was sceptical: 'There is no likelihood of our being able to suppress humanity's aggressive tendencies. In some happy corners of the earth, they say … there are races whose lives go gently by: unknowing of aggression or constraint. This I can hardly credit; I would like further details about these happy folk.'

2 **Tyfanny**, a young South African girl. She and Einstein exchanged several letters. In the final one, she wrote, 'I forgot to tell you, in my last letter, that I was a girl. I have always regretted this a great deal, but by now I have become more or less resigned to the fact,' to which Einstein replied, 'I do not mind that you are a girl, but the main thing is that you yourself do not mind. There is no reason for it.'

3 **William Du Bois**, the historian, civil rights activist and founder of National Association for the Advancement of Colored People.

4 **Rabindranath Tagore**, the Indian poet and polymath. They met in Einstein's Berlin home in 1930 and discussed topics such as science and truth and the nature of reality.

5 **Erwin Schrödinger**. Shortly after Schrödinger published his famous paper highlighting the absurdities of quantum mechanics with his simultaneously dead-and-alive cat, Einstein wrote to him, saying: 'From the point

of view of principles, I absolutely do not believe in a statistical basis for physics in the sense of quantum mechanics, despite the singular success of the formalism of which I am well aware.'

6 **President Franklin D. Roosevelt**. In 1939 Einstein co-signed a letter to the president written by the Hungarian physicist Leo Szilard, warning that Germany might develop a nuclear bomb.

7 **Seiei Shinohara**, a philosopher and translator. Shinohara originally wrote to Einstein in 1953 criticizing his role in the development of nuclear weapons, but the two later developed a friendly correspondence.

8 **Eduard 'Tete' Einstein**. Einstein's second son was diagnosed with schizophrenia aged 20 and spent much of his life in psychiatric institutions. Although Albert said to friends that it would have been better if Eduard had never been born, a newly discovered letter from father to son sheds a warmer light on their relationship. Albert writes: 'It seems to me it has been so long since I have seen you, and I am longing to have you around me once again.'

Nine ways to find out more

1 **Einstein online** (www.einstein-online.info), a web portal from Germany's Max Planck Institute of Gravitational Physics (otherwise known as the Albert Einstein Institute), provides a wealth of information about the great man's theories and their applications.

2 ***Einstein's Masterwork: 1915 and the General Theory of Relativity*** is John Gribbin's 2015 celebration of the theory's beauty and power.

3 ***Black Holes & Time Warps: Einstein's Outrageous Legacy*** (1994) is physicist Kip Thorne's homage to the great man's ideas, with a foreword by Stephen Hawking.

4 ***New Scientist*** magazine and its archive at www.newscientist.com contains many Einstein and relativity-related articles going back to 1989.

5 ***Dear Professor Einstein: Albert Einstein's Letters to and from Children*** (2002) contains many letters from young people and Einstein's replies to them.

6 **einsteinpapers.press.princeton.edu** holds the collected papers of Albert Einstein – a massive written legacy comprising more than 30,000 documents.

7 **www.alberteinstein.info** is another comprehensive digital archive of Einstein's scientific and non-scientific manuscripts, held at the Hebrew University of Jerusalem.

8 ***Relativity: The Special & the General Theory***, first published in English in 1920, is a semi-accessible account – with equations but no tensor calculus – by the man himself, which includes a memorable metaphor for space-time in the form of the flexible reference-mollusc.

9 ***Gravity from the Ground Up*** (2003) is an introductory guide to gravity and general relativity by Bernard Schutz.

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