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News

The Nature of Space and Time: An Evening of Speculation



What is space? What is time? And how do *we* fit into it all? These are questions not only for physicists and mathematicians, but also for philosophers and theologians. The [John Templeton Foundation](#) has gathered together just such an eclectic mix of people for a public discussion entitled [The Nature of Space and Time: An Evening of speculation](#) to be held at Emmanuel College in Cambridge on the 7th of September 2006. The discussion panel for the evening comprises some very eminent names indeed: mathematician and Fields medallist [Professor Alain Connes](#), [Rev. Dr. Michael Heller](#) from the Vatican Observatory, mathematicians [Professor Shahn Majid](#) and [Sir Roger Penrose](#) and theologian and physicist [Rev. Dr. John Polkinghorne](#).



A black hole at the centre of a galaxy. To understand what happens at the centre of black holes one needs a theory of quantum gravity. Image taken by the [Hubble Space Telescope](#), courtesy [NASA](#), [The Association of Universities for Research in Astronomy](#) and [The Space Telescope Science Institute](#).

The Nature of Space and Time: An Evening of Speculation

While we all have an intuitive understanding of space and time that is sufficient to get us through everyday life, when it comes to deeper questions about them one might expect to turn to physics. The two current fundamental theories of physics are general relativity and quantum mechanics. Whilst general relativity is extremely accurate for describing the universe on the macroscopic level and quantum mechanics similarly on the sub-atomic level, the two theories have never been united. Complications arise when one considers situations simultaneously involving both large mass scales and very small distance scales, currently described by general relativity and quantum mechanics respectively. In order to solve these problems, physicists have been searching for a theory combining the two called *quantum gravity* for several decades. Such a theory would not only give additional insight into how the universe began in the Big Bang, but also predict its ultimate fate.

There have been many efforts to formulate a theory of quantum gravity. Some of these take slightly modified but largely intact versions of general relativity and quantum mechanics and attempt to bring them together, whilst others, like string theory and the more modern M-theory, take different starting points, such as replacing fundamental particles by short bits of string. Although some progress seems to have been made, a complete unifying theory has so far proved elusive.

But whether they are complete or not, what do the existing theories tell us about the nature of space and time? Not much, according to some scientists. A particular failing of many current theories is that they make too many assumptions about the nature of space-time in their formulation: rather than *explaining* our intuitions of what space and time are, they take these intuitions as a starting point. Classical physics, for example, assumes both space and time to be continuous. In string theory space-time is assumed as an initial ingredient to be the multidimensional analogue of a smooth and continuous surface. In both cases, these properties of space and times are assumptions that go into the formulation of the theory, rather than a result of it. "The fundamental issue is that if space-time is to emerge from quantum gravity then it makes no sense to use our macroscopic intuitions about continuous space-time as a starting point," says panel member Shahn Majid, who is also organising a related research programme on noncommutative geometry at the Isaac Newton Institute in Cambridge.

The continuity of space-time is not the only intuitive concept that has been called into question. Even the seemingly simple notion of a point in space-time is far from straight-forward. In our everyday understanding of space-time, a point particle in it should be given by a number of coordinates; some of them describing its position in space and one describing its position in time. But one of the most fundamental assertions of quantum mechanics, Heisenberg's uncertainty principle, says that, at a tiny scale, it is impossible to measure both the spatial position of a particle and its momentum with arbitrary accuracy. If time is to be part of the quantum theory then one can expect the same problem as for momentum: the more accurate your measurement of spatial information, the less accurate your measurement of information concerning time and vice versa. Thus, the idea of a point in space-time an entity specified by coordinates is, in a sense, meaningless.

So it can be argued that a unified theory of quantum gravity needs to rid itself of many of the classical notions of space-time from the outset. To do this, it needs a far more general mathematical theory of space-time and even of space in other words of geometry than the one we learn about at school. A prime candidate for such a theory, according to Shahn Majid, is what is called *noncommutative geometry*.



The universe at a large scale. Image taken by the [Hubble Space Telescope](#), courtesy B. Mobasher ([The Space Telescope Science Institute](#) and [The European Space Agency](#)) and [NASA](#).

Noncommutative geometry takes an algebraic approach to understanding space. Algebra is something that also enters classical geometry: given a space, we can describe lines, planes and other surfaces in it by algebraic equations, and we can define functions which take points in the space as their input. The algebraic properties of these equations and functions can encode the properties of the space they are based on.

Noncommutative geometry, like classical algebraic geometry before it, works only with the algebraic features of the underlying space, whatever that space may be. Some particular algebraic properties of classical geometry that have to do with the *laws of commutation* are missing in the algebra of noncommutative geometry, giving it its name and making it far more general than its classical counterpart. Crucially, it does away with the notion of a point and the assumption of continuity in the conventional sense. "It could be the right setting for its own, and perhaps correct, approach to quantum gravity," says Shahn Majid, "it does not assume either a continuum or a discrete space as its input, but can include both as special cases."

Even as a purely mathematical theory, noncommutative geometry is not yet fully explored. And results from this mathematical research may tell us things about the properties of a quantum gravity theory that may otherwise not be obvious – an interesting interplay between pure maths and physics. "The possibilities within noncommutative geometry at a mathematical level provide constraints on what the unknown theory of full quantum gravity can be. The geometry's own internal consistencies can be a guide to the deeper unknown theory. It's what I call the algebraic approach to quantum gravity," says Majid.

At this point you may be wondering what the general public could possibly contribute to such a technical and mathematical debate. Quite a lot, according to Majid, since the physics and maths still fall short of answers to the deeper questions: "Without quantum gravity we do not have honest answers to these questions. If one does not know what time is, then what does it mean to exist (which usually means at some moment in time)? What is existence? And what about free will? At this point we can hope to have a very broad debate involving theologians, philosophers and the general public. Personally I think that theoretical physics can only go so far with its current ideology and methods, we actually need some completely fresh angles to make progress."

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So if you think that you have something to contribute, or simply want to listen in on the debate, you can [register online now](#). Admission is also free on the door but capacity is limited. And since no-one has yet developed a working time machine I would recommend registering in case they run out of space.

Further reading

You can learn more about string theory in the *Plus* article [Tying it all up](#) and on the [String theory website](#).

Adrian Potter



Plus is part of the family of activities in the Millennium Mathematics Project, which also includes the [NRICH](#) and [MOTIVATE](#) sites.