Isaac Newton Institute for Mathematical Sciences

Global Problems in Mathematical Relativity

8 August to 23 December 2005

Organisers: PT Chrusciel (Tours), HE Friedrich (Golm), KP Tod (Oxford)

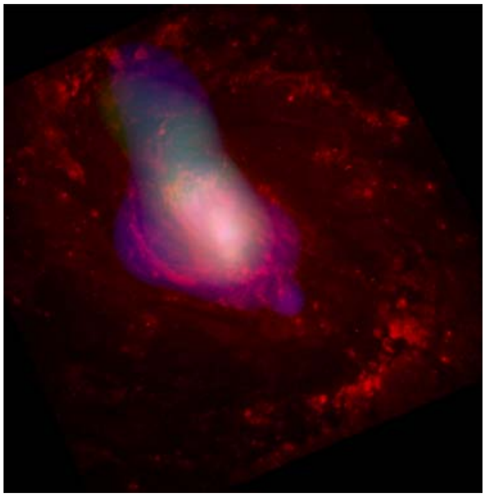
Einstein's theory of Special Relativity celebrates its centennary this year. So completely successful has it been, that it is impossible to imagine physics without it. It is so much a part of our framework of thought that we almost don't see it as a theory. As Minkowski famously predicted in 1908, space by itself and time by itself have 'withered away' and in their place we think in terms of space-time, which now seems utterly natural. Special Relativity is straightforward enough to be taught to second-year undergraduates, and it is hard to imagine that there could be unsolved mathematical problems in the theory awaiting solution.

Its younger sibling, Einstein's theory of General Relativity, has just turned 90 this year and enjoys a rather different reputation. When Eddington, in the early days, was asked if it was true that only three people in the world understood Relativity, it was General Relativity that he was being asked about. For a long time it was seen as the last word in mathematical complexity but along with that it was always clearly a theory of the physical world, and in fact a very successful one. Predictions of the theory are verified to many significant figures, classically in the solar system, particularly in the observation of planetary orbits, and more recently in observations of binary pulsars. These latter observations provide indirect evidence of the existence of gravitational radiation, behaving just as the theory predicts. There are substantial programmes in hand to provide direct evidence of gravitational radiation, and even to contemplate gravitational wave astronomy.

While General Relativity must compete with rival theories in its detailed predictions, some features of the theory have been incorporated into our framework of thought almost as firmly as have those of Special Relativity. It is hard to imagine that curved space-time as a theory of gravity and a model of the universe will ever be dislodged. Where the sibling relativities are strikingly different is that there are very definitely mathematical problems in General Relativity awaiting solution, and that is the topic of this programme.

There are two approaches to saying where the mathematical problems lie: one may ask how this geometrically-based subject relates to other mathematical disciplines involving geometry, and how does one set about using the theory. For the first, it can be said that almost any idea useful in differential geometry will find application in General Relativity, but often with a distinctive slant because the geometry of GR is Lorentzian instead of Riemannian. For the second, one can think of GR as determining a space-time as a geometry evolving from suitable initial data. Now there are many problems: how does one construct the data? how does the evolution proceed and how may one reliably compute it, to extract quantitative predictions? what singularities may form and are they 'censored' inside black holes? indeed, what kinds of black holes are there?

Recent and rapid progress is taking place in the study of these and related problems in the mathematical study of General Relativity, and this is what this programme at the Newton Institute will be devoted to.



The Chandra X-Ray Observatory produced this composite X-ray (blue and green) and optical (red) image of the active galaxy NGC 1068 showing gas blowing away in a high-speed wind from the vicinity of a central supermassive black hole. (NASA-MSFC)