The dimensionality of the world

Multiple dimensions and the problem of time.

Although Bee has recently written an amazing and thorough article over at Backreaction with virtually everything one needs to know about extra dimensions in physics, let me add a sort of footnote in the form of some naive musings, a couple links and a Hertzian digression in this somewhat iffy post.

Multiple dimensions and the problem of time
As a student, i was in love with Kaluza-Klein theory and its extremely elegant explanation of electromagnetism as the purely geometrical effect of a fourth spatial dimension. The really magic thing is that the electromagnetic energy momentum tensor (in four dimensions) arises as a consequence of an *empty* five-dimensional space where particles follow geodesics; in other words, photons are purely geometry, just as gravitational forces. The problem, of course, was to explain why we don't measure that fifth dimension. Kaluza just prescribed that no physical quantity depended on it, while Klein tried a somewhat more satisfactory solution by compactifying it to an unobservable size, and making it periodic, just as the second dimension of a long hose, which becomes one-dimensional when seen from a distance. Unfortunately, this beautiful picture seemed to lead to insurmountable difficulties with chirality or the mass of the electron, unless one goes the string way and adds more compact dimensions to our universe. I thought Kaluza-Klein theories were all but abandoned in their original 5-dimensional form these days, but following some links in the recent review article by Orfeu Bertolami, The Adventures of Spacetime, proved me utterly wrong. There's been quite a lot of activity in the area during the last decade, leading even to a Space-Time-Matter consortium, a sort of physicists' club promoting 5-dimensional gravity theories without compactification. The consortium is coordinated by P.S Wessan, and has quite a few members and interesting publications: see for instance this comprehensive review of KK theories of gravity for an introduction to Wessan and friend's ideas. What i find compelling about their approach (and what, at the same time, of course reveals my prejudices) is that they tackle multidimensional physics from the point of view of general relativity, rather than particle physics. However, i guess that a word of caution is in order: i've read very little about these (to me) novel approaches to KK theories, and i'm not yet ready to endorse them; if they were right (and i definitely wish they were), they'd be quite revolutionary: for instance, they explain quantum indeterminacy as a result of particles travelling in higher dimensions... that'd be extremely cool (and actually make real one of my silly ideas of old), but perhaps too cool to be true? Well, i'll leave it for you to decide (as for me, i think i'm going to read Wessan's book, Five Dimensional Physics, lest student dreams can really come true!).

Returning to Bertolami's paper, let me mention that it is part of a forthcoming book entitled Relativity and the Dimensionality of the World, the good news being that the above link points to freely available versions of many of its chapters, written by various authors, including Wessan and G.F.R. Ellis. The latter writes about his rather original ideas on time in General Relativity, and the Block Universe idea, familiar to all relativists, of a world represented as a frozen 4-dimensional whole. Ellis observes that such a representation clearly suggests that time is an illusion: the entire universe just *is*. The problem is that such a view seems incompatible with irreversible, macroscopic phenomena, as well as with the fundamental indeterminism inherent to quantum mechanics. To take into account these facts of life, Ellis proposes an *Evolving Block Universe*: time passes; the past is fixed and immutable, and hence has a completely different status than the future, which is still undetermined and open to influence; the kinds of `existence' they represent are quite different: the future only exists as a potentiality rather than an actuality. The point being that our regular, predictable universe models are based on too simplistic assumptions and oversimplified systems, and that taking into account realistic, emergent ones renders the future under-determined. Although very interesting from a philosophical point of view, Ellis ideas need much fleshing out before becoming a solid theory of anything. But still, he makes many a fine point, and quite a lot of good questions worth thinking about.

A digression: Hertz's mechanics
Finally, Bertolami's paper draw my attention to a facet of Heinrich Hertz's work i was totally unaware of, namely, his contributions to the interpretation of classical mechanics. After gaining a place in the history of physics with his experimental confirmation of the existence of electromagnetic waves, and before his tragic death when he was only 37, Hertz wrote a book, The Principles of Mechanics Presented in a New Form, where he proposed a formulation of Newtonian physics freed of forces, using instead a variational principle. According to Hertz's

principle, particles move along paths of least curvature, where the (three dimensional) metric is defined by constraints instead of forces. Similar principles were proposed by Gauss and d'Alembert before Hertz, but the latter was notorious (if only ephemerally) for pushing to the forefront a view of space-time defined by matter in a purely relational, Leibnizian fashion: Hertz tries to derive his *system of the world* from material particles alone. Unfortunately, i've found little information on-line on Hertz's ideas, which seem to be better known to philosophers due to their influence on Wittgenstein (who directly mentions Hertz in his Tractatus). For those of you with a philosophical soft spot, this paper presents a re-interpretation of some of Wittgenstein's ideas under a Hertzian perspective. As a physicist, i find Hertz's ideas interesting almost only as a historical curiosity, and don't know how relevant they really are to modern epistemology: comments welcome! 😉
