Minkowski's Legacy in Higher Dimensions

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Modern theories that attempt to unify gravity with standard-model interactions generally do so with the aid of extra spacetime dimensions. They thereby owe an enormous debt to Minkowski, who famously announced 100 years ago that "space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality". In fact it is likely that Nordstrom and Kaluza, who created the first unified theories of gravity and electromagnetism in five dimensions, were inspired at least indirectly by Minkowski's four-dimensional interpretation of Einstein's successful unification of electromagnetism with mechanics (special relativity). Modern "theories of everything" such as string and M-theory trace their ancestry directly back to Kaluza and Klein in the 1920s, though they require many more dimensions. They remain conceptually Minkowskian, however, in that the extra coordinates are almost always assumed to be lengthlike (or more rarely, timelike) in dimension. The non-appearance of these extra dimensions in the everyday world is typically explained by means of closed topology and compact scale (Klein through string and M-theory), or alternatively by postulating that they are inaccessible to standard-model fields (brane theory). Wesson and his coworkers have proposed an alternative approach to unification in higher dimensions, known as Space-Time-Matter (STM) theory, in which the extra coordinates are not necessarily lengthlike or timelike. I outline this theory with emphasis on possible implications for experiment, and for cosmology in particular. If the STM approach proves correct, then it may be necessary to extend Minkowski's pronouncement so that "matter by itself, along with space and time by themselves, are doomed to fade away into mere shadows, and only a union of the three will preserve an independent reality."