A multidisciplinary approach to the theory of emergent states

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Our physics textbooks are dominated by examples of simple, weakly-interacting microscopic states. But the actual physical states of our world are often most effectively described as emergent, meaning that they are strongly-correlated and dominated by properties that emerge as a consequence of interactions and are not part of the description of the corresponding weakly-interacting system. Such states often have a phenomenologically description but no clear microscopic connection to the simple states described in our textbooks. This talk proposes a microscopic connection of weakly-interacting states and emergent states through dynamical symmetries that imply unique truncations of the full Hilbert space to a collective subspace where emergence lives. Much as Einstein used the equivalence principle to argue that gravity must be a property of spacetime and not of specific objects in spacetime, it will be proposed that emergence is in essence a property of a symmetry-truncated Hilbert space and not of specific microscopic systems whose wavefunctions may reside in that space. Thus emergent properties achieve a universality largely independent of underlying microscopic details, as is observed for many physical systems. As a concrete example of applying these ideas it will be shown that atomic nuclei, high-temperature cuprate and iron-based superconductors, and monolayer graphene in a strong magnetic field – which have little in common microscopically – exhibit a remarkable universality in emergent behavior that is described quantitatively by the ideas presented above.