

The Weight of the Vacuum: A Scientific History of Dark Energy, by Helge S. Kragh & James M. Overduin (Springer, Heidelberg), 2014. Pp. 113, 23.5 × 15.5 cm. £44.99/\$54.99 (paperback; ISBN 978 3 642 55089 8).

This is an exceptionally good, short guide to the history of physicists' understanding of the energy of empty space. The dark energy of this book is 'dark' not simply in the sense that it does not interact with electromagnetic radiation, but in the deeper philosophical sense that we are in the dark in more ways than one: its properties are in the realm of unknown unknowns. During the 20th Century the concepts of 'ether' and 'vacuum energy' underwent several phase changes. They are documented clearly in this account, which is arranged in two halves: before and after 1964.

The advent of quantum theory transformed the debate on the nature of the vacuum. The zero-point energies of field theories swept aside the *pneuma* of the Stoics as well as the ethereal world-view of the Victorian era. In 1911 Max Planck introduced zero-point energy, which he admitted was a ghostly entity, outside the scope of classical physics. Others from the German school of quantum theory, notably Walther Nernst, Wilhelm Lenz, and Emil Weichert, developed hypotheses in which a medium remained after the removal of all matter from space. Everything changed in the 1930s with Einstein, Lemaître, and the cosmological constant Λ , as well as Hubble's discovery of a linear correlation between the recession velocities and the distances of galaxies. Einstein began to speak of "empty space" having physical properties. Lemaître always regarded Λ as a vacuum energy, in part inspired by his former mentor Eddington. However, Lemaître's insight attracted little following.

The second half of the account opens with the accidental discovery of the cosmic microwave background in 1964, which was immediately interpreted as fossil radiation from the earliest Universe. Historians of science have established that the concept of an inflation era in the early Universe begins in the USSR in the late 1960s. An explosion of interest followed in the 1980s when inflation and the false vacuum became mainstream. But at the same time cosmologists tended to dismiss the Λ term. The great shock, and it was a shock, that convulsed cosmology in 1998 was the discovery of the accelerating Universe. That led to the emergence of a concordance cosmology in which the values of the fundamental parameters are known with exquisite precision. This is an excellent brief history of cosmology. I expect to cite it many times in my academic papers and books. — SIMON MITTON.