Book Reviews

Cosmic Distances

The Cosmological Distance Ladder. Distance and Time in the Universe. MICHAEL ROWAN-ROBINSON. Freeman, New York, 1985. xii, 355 pp., illus. $35.95.

Scientists only mildly interested in astronomy may not have noticed that the universe is twice as big on Mondays, Wednesdays, and Fridays as it is on Tuesdays, Thursdays, and Saturdays. On Sundays, it's a toss-up. None of this is very amusing to the professional astronomer, who likes to think of astronomy as the first of the exact sciences, its roots reaching far back into antiquity.

Our current understanding of the size of the universe is based on measurements of the Hubble constant. Late in the 1920's, Edwin Hubble of the Mount Wilson Observatory was able to demonstrate that distant galaxies exhibit spectra in which, most noticeably, the absorption lines due to calcium are systematically redshifted—shifted toward longer wavelengths—in proportion to the galaxy's distance. This redshift is now universally interpreted as a velocity shift. The more distant a galaxy, the greater its redshift, and the greater its recession velocity. As a galaxy's recession velocity approaches the speed of light, two effects reduce the radiation we receive. First, the observed light is shifted to longer wavelengths, where the energy of radiation quanta is reduced; second, the arrival rate of the quanta diminishes, again reducing the amount of energy reaching us in a given interval. These two effects conspire to reduce the energy received from a galaxy. The energy is reduced to nothing when the galaxy recedes at the speed of light, and the galaxy drops from sight. We speak of a cosmic horizon, a distance beyond which we cannot observe. In a practical sense this horizon defines the edge of the observable universe and its size.

The Hubble constant, H_0, is the rate at which a galaxy's recession velocity increases with increasing distance. If the velocity is measured in kilometers per second and the distance to the galaxy is measured in megaparsecs (1 Mpc roughly equals a distance of three million light years) then the value of H_0 can be expressed in km/sec per Mpc. Over the past decade H_0 has been measured through increasingly varied approaches by two separate groups, one guided by Gerard de Vaucouleurs at the University of Texas at Austin, the other led by Allan Sandage at the Carnegie Institution of Washington and Gustav Tammann at Basel. Respectively, these groups have repeatedly argued for values H_0 = 100 km/sec per Mpc and H_0 = 50 km/sec per Mpc. As Rowan-Robinson tells us in the preface to his book, each group insists that its results are incompatible with those of the other.

The book has two aims. The first is to clarify the points of disagreement between these two groups; the second is to provide a self-contained textbook for undergraduates in their final year of study. Clearly, it is difficult to tackle both aims at the same time. The undergraduate generally will need to understand broad principles, whereas the sources of disagreement between professional groups tend to evolve around finer detail. Rowan-Robinson faces this difficulty by proceeding step by step up the ladder to increasing distances. Since distance estimates are largely based on astrophysical models, the author provides much of the required background. We need to know how a star orbits around a binary companion before the dynamics of the orbit can be used to compute a distance to the star pair. Similarly, we need to understand how submicroscopic dust grains selectively absorb radiation of different colors if we are to properly account for the dimming of stars by interstellar dust. Errors accumulate as one climbs up the distance ladder; mistakes made in estimating the distances to nearer stars and clusters propagate to reappear first in distance estimates for the nearer galaxies and then in distance measures for clusters of galaxies observed at extreme redshifts. The author takes pains to provide the reader with all this required information. Readers of *Science* will find this a valuable book that explains the methodology and the pitfalls of cosmic distance estimates clearly and with ample charts, tables, and references for those wishing to probe the subject in ever greater detail. Whether or not Rowan-Robinson's analysis of the differences between currently claimed values of the Hubble constant—or his own personal preference for an adjusted value, H_0 = 67 km/sec per Mpc—will be accepted by specialists in the field probably is not of greatest importance. What is more significant is that Rowan-Robinson has produced an informative book that guides the reader through the general problem of estimating cosmic distances, points out difficulties along the way, and assembles background data and references to the literature that a large number of astronomers and students will find useful.

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Atmospheric Evolution

The Carbon Cycle and Atmospheric CO_2. Natural Variations Archean to Present. E. T. SUNDQUIST and W. S. BROECKER, Eds. American Geophysical Union, Washington, D.C., 1985. x, 627 pp., illus. $28. Geophysical Monograph Series, 32. From a conference, Tarpon Springs, Fla., Jan. 1984.

Researchers concerned with atmospheric evolution have been heard to complain that there are no samples of ancient atmosphere, but the complaint can no longer be sustained. Snow on the permanent ice caps of Greenland and Antarctica incorporates air, which becomes trapped in bubbles as the snow is compressed and converted into ice. This unpromising resource has been successfully exploited by research groups in Europe to derive a record of atmospheric change that extends more than 100,000 years into the past. Results of this research, reviewed in this collection of 46 papers, contain clear evidence that the partial pressure of atmospheric carbon dioxide rapidly increased by about 50 percent at the end of the last ice age, some 10,000 years ago. This remarkable observation has stimulated much new research on the geochemical cycle of carbon, which is well summarized in this volume.

Photosynthetic plankton in the surface layers of the ocean extract carbon dioxide from the surrounding water and the atmosphere and incorporate the carbon into their cells. Moribund cells and particles of organic carbon settle into deeper waters, where they are consumed by respiring organisms and converted back to dissolved inorganic carbon. This biological activity increases the concentration of carbon in the deep sea at the expense of the surface ocean and atmosphere. The papers in this collection are in general agreement that the sudden rise in atmospheric carbon dioxide at the end of the ice age was caused by a reduction in the effectiveness of this biological pump. General theoretical analyses in three papers show how a change in biological activity can lead to a transfer of carbon out of the deep sea and an increase in the atmospheric partial pressure. But there is no agreement on the processes responsible for the change in biological activity. Three competing hypotheses are presented and developed in some detail. An interesting prediction of the theories, not yet confirmed by observation, is that the oxygen content of the deep sea decreased significantly during the ice age as a result of increased respiration of settling organic particles.

Many papers in this collection are devoted to the search for further diagnostic observations that might distinguish between the competing theories. Measurements of the isotopic composition of carbon in sea floor sediments show promise, as do observations that reveal periods of dissolution of carbonate minerals. The book makes it clear that this field of research is developing rapidly, both observationally and theoretically.

The evidence for longer-term changes in atmospheric carbon dioxide is by no means as clear, but the case is becoming stronger. One hundred million years ago, during the Cretaceous Period, the earth apparently enjoyed a warmer climate with much less contrast between tropical and polar temperatures. Two papers in the collection are devoted to theoretical efforts to explain the change in climate since then. These papers explore the potential impact of various aspects of the climate system and agree in assigning an important role to a presumed higher partial pressure of carbon dioxide in the atmosphere. Increased partial pressure of carbon dioxide increases the surface temperature by reducing the rate at which the globe cools to space by emission of infrared radiation. Observational evidence for high carbon dioxide partial pressures at this time is provided by the isotopic composition of sediments and by carbonate mineralogy, but the way in which these records should be interpreted is by no means clear. Theoretical studies indicate that high carbon dioxide during the Cretaceous could be a consequence of an enhanced rate of release of carbon dioxide from volcanic and metamorphic activity and a reduced rate of consumption of carbon dioxide in the chemical weathering of continents at a time when sea level was high and the quantity of land exposed relatively small.

Other papers present observations and theory that relate to atmospheric carbon dioxide at times extending back to the Archean Era of earth history, more than 2.5×10^9 years ago. Though the history is now known only in broad outline, this collection makes it clear that atmospheric carbon dioxide has fluctuated naturally on all geological time scales. The record is being read with increasing confidence. The climatic, geochemical, and biological impacts of these fluctuations are being evaluated. The excitement of this new area of research is captured by this volume, which also brings the reader nearly up to date. Research on the carbon cycle and its natural variations in the past will make our predictions of the future impact of fossil fuel burning and deforestation much more secure.

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The Adoption of Anesthesia

A Calculus of Suffering. Pain, Professionalism, and Anesthesia in Nineteenth-Century America. MARTIN S. PERNICK. Columbia University Press, New York, 1985. xvi, 421 pp., illus. $35.

Traditional histories of medicine have focused on scientific discoverers and their discoveries; they make heroes of the discoverers and interpret the innovations as contributions to the unfolding of science and reason in Western society.

Within the last decade a new generation of medical historians has moved in significant new directions. Rather than glorifying a few leading figures in the scientific-medical community these new historians have expanded their focus to look at physicians within the broader boundaries of American society. In doing so, they have introduced variables such as class, race, and gender into their analyses and have interpreted medical events, doctors, and the medical profession within the context of American culture.

Martin S. Pernick's *A Calculus of Suffering* is a welcome addition to the new medical history. While it focuses on a major medical innovation—the introduction of anesthesia in surgery—this study moves well beyond the history of the discovery. Pernick asks how mid-19th-century physicians, the first generation to confront the option of surgery under anesthesia, integrated anesthesia into their practice. In particular, he seeks to explain how they decided who should receive anesthetics and who should not. He also examines broader issues such as the relationship of anesthesia to changing medical views of pain, contemporary reform movements, and the entrance of women doctors into surgery.

Pernick shows that mid-19th-century physicians did not hail the discovery of anesthesia as a major scientific triumph. Instead, they responded to it cautiously, sometimes quite critically, and their reactions depended as much on social and cultural factors as they did on medical thought.

Physicians' ideas about pain influenced their responses to anesthesia. Pernick shows that homeopaths, hydropaths, and other advocates of the healing power of nature defined health as natural and pain as unnatural, indeed as punishment for unhealthy living. Rejecting surgery as artificial and intrusive, they rejected anesthesia for the same reason, advocating instead a regimen of diet, exercise, and natural living that they believed would promote health and prevent disease and pain.

The natural healers who shunned all artificial attempts to prevent pain stood at one end of the medical spectrum. At the other end were the heroic physicians, those who bled, blistered, and drugged their patients. They believed that pain was natural and often a necessary part of the healing process. Their belief in the curative component of pain thus led heroic physicians to essentially the same conclusion as the natural healers, the rejection of anesthesia. In cases where heroic doctors defined pain as a disease in itself, however, anesthesia became an appropriate therapy. Pernick makes the irony clear. In such a case, a patient in pain would encounter a harsher response from the natural healers, who advocated mild therapeutics, than she or he would from the heroic physicians, who would respond sympathetically to the disease of pain and might treat it medically with surgery under anesthesia.

Midway between the natural healers and the heroic physicians stood the advocates of "conservative medicine." Conservative physicians, according to Pernick, adopted a utilitarian approach to anesthesia, using it when they believed it offered the best route to cure and rejecting it in other cases. Pernick argues that with this alternative approach of conservative physicians utility, relativism, and individualism became