Who made the sky?

William B. McKinnon

Origin and Evolution of Planetary and Satellite Atmospheres. Edited by S.K. Atreya, J.B. Pollack and M.S. Matthews. *University of Arizona Press: 1989. Pp. 881. $45, £38.95.*

IN the oldest near-eastern mythologies, the world was created in the fertile union of sky and earth. Today, the curtain is drawn partly back, and we ask who or what created the creators. This questioning is exemplified by the latest addition to the University of Arizona's Space Science Series — a volume whose subjects are the origins and fates of the different skies (atmospheres) of our Solar System. The atmospheres are not examined to the exclusion of the solid worlds to which they are intimately coupled (if the solid worlds exist); rather, atmospheres serve as a focus. Atmospheres are, after all, observable: we have also directly sampled the atmospheres of the Earth, Venus and Mars, and are finally on our way (with the launch of Galileo) to sample Jupiter's.

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Hidden in a cloud of gas and dust is the nucleus of Halley's comet: a 16 × 8 × 8 km chunk of possibly porous ices, rock mineral grains and organic matter. Such bodies may have been the bringers to the terrestrial planets of air, water and organic precursors to life and may also be eroders of atmospheres and destroyers of climates and ecosystems.

As usual in the Arizona series, this book is based on a conference and, as usual, the text goes far beyond the proceedings. What the reader will find is 22 comprehensive chapters written by 50 carefully chosen experts. Some chapters are simple reviews, others present a wealth of new information. The volume is well-organized into five parts. The first two cover conditions in the early Solar System and so-called 'primitive' bodies (comets, asteroids and their brethren). The other three are devoted to the atmospheres of the terrestrial planets, the deep atmospheres of the giant outer planets, and the satellites of the giant planets. The intended readership is wide, from graduate students to the most senior researcher.

Several early chapters are noteworthy for the non-specialist. Irvine and Knacke and Jessberger *et al.* have put together micro-compendiums on the composition and chemistry of interstellar clouds (from which planets and stars are born) and comets (possibly the least processed stores of interstellar matter), respectively. The literature of interstellar clouds and their gas and dust is vast, and it is most gratifying to have this material collated and synthesized. Somewhat differently, our knowledge of cometary compositions has been revolutionized by the Halley encounters in 1986, but it is difficult to find a good overview of what comets are now estimated to be made of. A detailed paper on solar nebula chemistry by Prinn and Fegley is not a review at all, but a significant addition to the literature of this topic, outlining the myriad processes that lead to disequilibrium chemistry during the cooling of the nebula, and thus to new predicted compositions for planetesimals (such as anhydrous silicates and ice rather than hydrated silicates). All three chapters, and several related ones, can be profitably read by anyone interested in the composition of any part of any planet or satellite.

One clear message delivered in this book is how far we have come in understanding the climatic evolution on the terrestrial triad — Venus, Earth and Mars. W.W. Rubey's original conception of an Earth accreted cold and then slowly releasing its atmosphere and ocean because of volcanism has been swept away. The planets accrete hot, and any world larger than Mars-sized is melted and degassed. The atmospheres so created are subject to further additions or losses due to impacts (Ahrens *et al.*). Losses also occur via thermal diffusion, solar wind stripping and hydrodynamic blow-off (Hunten *et al.*). Volatile gases and water can recombine with the planetary interior by dissolving in global magma oceans or by quieter chemical recombination. Climates are then subject to marvelous feedbacks between the interior and atmosphere (Kasting and Toon; Schubert *et al.*). That the Earth has been habitable for most of its history is a central focus of the chapter by Kasting and Toon, and it is remarkable that a story can be told at all. Much work remains to be done, but the authors, in arguing that an Earth-like planet orbiting a solar-type star can maintain surface liquid water at orbital distances of about 0.95 to about 1.5 astronomical units (the orbit of Mars), have tantalizingly extended their conclusions to other solar systems.

Important constraints on the origins of terrestrial planet atmospheres are provided by noble-gas inventories and their isotopic compositions (dealt with in several chapters). For example, these may imply that the Earth and other terrestrial planets accreted within the roughly 1–10 million-year lifetime of the solar nebula, and not over a much longer span of time, as has been generally thought. It is also clear from the chapter by Lunine *et al.* that similar information will be crucial for understanding the formation and evolution of Titan's thick, nitrogen–methane atmosphere. This information should be provided by the Titan probe on board the planned Cassini mission. (It is a shame that Ganymede and Callisto around Jupiter do not possess atmospheres. What stories they could tell us!) It is also thought-provoking to read this chapter with the new knowledge of Triton's nitrogen-methane atmosphere and the evidence for a 'heavy' gas, such as carbon dioxide or nitrogen, around Pluto.

It is truly exciting to read through this volume. The Arizona series traditionally focuses on individual bodies or classes, but the challenge here of thinking about the histories of the atmospheres of such diverse words as the Earth, Jupiter and Triton, has led many of the authors to broader, synergistic views and thinking. The reader will be similarly enticed. This book naturally belongs on every planetary scientist's bookshelf, and because of its broad sweep, should find a ready home among astronomers and geoscientists as well. □

William B. McKinnon is in the Department of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, Saint Louis, Missouri 63130, USA.