Comparative Planetology as Key to the Origin & Evolution of Atmospheres

SUSHIL K. ATREYA[1]
[1]*University of Michigan, United States*

It was generally assumed that the history of the solar system may be found in the giant planets, Jupiter in particular. At 320 ME (Earth Masses), Jupiter is so big that none of the material it acquired during formation could ever escape. What's that material? The core accretion model first proposed by H. Mizuno could provide a clue. According to this model, the core of the planet formed initially from grains of dust, ice, rock, metal and refractory material, trapping the gases. Once the core grew to a critical mass of 10-15 ME , it gravitationally captured most volatile of the gases in the surrounding protoplanetary nebula—H and He and Ne—which led to the collapse of the planetary nebula. The atmosphere resulted from these gases and those released from the core during accretionary heating. This scenario would then predict that the elemental composition in Jupiter's atmosphere should reflect the primordial solar nebula composition. The in situ measurements by the Galileo probe revealed that contrary to expectations the abundances of heavy elements (mass>4He)—Ar, Kr, Xe, C, N and S relative to H were enriched by a factor of 4±2 compared to the values in the Sun. O/H could not be measured since the probe entered a dry spot of Jupiter. However, water must be measured as it is suspected to comprise between 50-70% of the original core, and was the original carrier of the heavy elements. Even in the absence of the oxygen elemental abundance, it is clear that the core accretion model needs extra material added to Jupiter. This led to the cold icy planetesimal models. It is also clear that that even after the measurements of water are done by Juno in 2016, that Jupiter alone cannot tell how the giant planets formed, let alone the solar system. A comparison with at least the other gas giant, Saturn, and eventually with the icy giants, Uranus and Neptune is needed. A similar situation exists for the rocky inner planets. Here the question of life and habitability becomes central, when investigating their formation and evolution. Titan, the Mercury-sized moon of Saturn, could be an important analog to primordial conditions on Earth. The methane cycle appears similar to the hydrological cycle, the photochemical smog may contain pre-biotic molecules, and the origin of Titan's nitrogen atmosphere seems to be similar to the source of N2 on Earth, Mars and Venus. As on the giant planets, the chemistry of the upper, middle and the lower atmosphere, thermodynamics of the troposphere and convection from the interior are all coupled and need to be studied as a system in order to understand how the atmospheres in the solar system formed and how they evolved. As we embark on ever more ambitious exploration of our solar system and other planetary worlds, we need to remind ourselves that this is a human endeavor which will benefit immensely from joint efforts between Asian nations, United States and Europe, to name just a few potential partners. Let's explore together!