The Origin and Evolution of an Atmosphere on Titan: What are the Isotopes and Other Observational Constraints Telling us?

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Titan is unique amongst planetary moons. Of the nearly 175 known natural satellites in the solar system, Titan is the only one with a large atmosphere. Compared to Earth, Titan's atmospheric pressure is 50% greater and the atmosphere 4 times denser, yet its surface density is only about one-third that of the Earth, implying that rock and ice make up Titan in roughly equal proportions. Though this presentation focuses on the atmosphere, there is strong coupling between it and the interior of Titan. Today, molecular nitrogen comprises nearly 94% of Titan's atmosphere by volume; methane is 5.65% and the rest is in the form of trace constituents resulting from the chemistry between nitrogen and methane. Observational evidence, particularly primordial argon, makes a compelling case that Titan's nitrogen was not delivered as N_2, i.e. it is not primordial [1,2]. The secondary nitrogen atmosphere most likely formed from nitrogen bearing molecules in Titan's building blocks, most likely ammonia [1]. The origin of methane is less clear, but available evidence favors its formation also on Titan from other (primordial) carbon-bearing species [2,3]. A comparison of the isotopic ratios in hydrogen (D/H), nitrogen ($^{15}N/^{14}N$) and carbon ($^{13}C/^{12}C$), in particular, in Titan's atmosphere with the isotopic ratios in other solar system objects, including comets, provides further insights into its origin of Titan's atmosphere and the role of impacts amongst other phenomena. The fate of Titan's atmosphere is intricately tied to the cycle of methane on Titan, so that the atmosphere we see today on Titan may not be eternal, at least not in its present form [1,4]. Here, we will discuss above aspects of the origin and evolution of Titan's atmosphere employing all available observational constraints including the stable gas isotopic ratios, and suggest the critical missing pieces of the puzzle that ought to be addressed in any future missions to this ocean world.

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Keywords: Titan, Ocean Worlds, Origin and Evolution, Comets, Future Missions

