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ALMA observations of Titan's atmospheric chemistry and seasonal variation

MARTIN CORDINER, NASA Goddard Space Flight Center

Titan is the largest moon of Saturn, with a thick (1.45 bar) atmosphere composed primarily of molecular nitrogen and methane. Photochemistry in Titan's upper atmosphere results in the production of a wide range of organic molecules, including hydrocarbons, nitriles and aromatics, some of which could be of pre-biotic relevance. Thus, we obtain insights into the possible molecular inventories of primitive (reducing) planetary atmospheres. Titan's atmosphere also provides a unique laboratory for testing our understanding of fundamental processes involving the chemistry and spectroscopy of complex organic molecules. In this talk, results will be presented from our studies using the Atacama Large Millimeter/submillimeter Array (ALMA) during the period 2012-2015, focussing in particular on the detection and mapping of emission from various nitrile species. By combining data from multiple ALMA observations, our spectra have reached an unprecedented sensitivity level, enabling the first spectroscopic detection and mapping of C2H3CN (vinyl cyanide) on Titan. Liquid-phase simulations of Titan's seas indicate that vinyl cyanide molecules could combine to form vesicle membranes (similar to the cells of terrestrial biology), and the astrobiological implications of this discovery will be discussed. Furthermore, ALMA observations provide instantaneous snapshot mapping of Titan's entire Earth-facing hemisphere, for gases inaccessible to previous instruments. Combined with complementary data obtained from the Cassini Saturn orbiter, as well as theoretical models and laboratory studies, our observed, seasonally variable, spatially resolved abundance patterns are capable of providing new insights into photochemical production and transport in primitive planetary atmospheres in the Solar System and beyond.