Microwave spectroscopy of complex molecules around the young protostar Chamaeleon MMS1

Martin A. Cordiner¹, Steven B. Charnley¹, Eva S. Wiström¹ & Robert G. Smith²

¹ Astrochemistry Laboratory, Solar System Exploration Division, Code 691, Science and Exploration Directorate, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

² School of Physical, Environmental, & Mathematical Sciences, The University of New South Wales, Canberra, Australia.

Observations are presented of emission lines from organic molecules at frequencies 30-100 GHz in the vicinity of the extremely young, chemically rich, very low-luminosity protostar and candidate first hydrostatic core Chamaeleon MMS1. Column densities are derived and emission maps are presented for species including polyynes, cyanopolyynes, sulphuretted carbon-chains and methanol. Emission from the carbon-chain-bearing species peaks very near to the protostar; methanol peaks about 0.1 pc further away. The mean molecular hydrogen number density is calculated to be 10⁶ per cc. and the gas kinetic temperature is in the range 4-7 K. The abundances of long carbon chains (including C6H and HC7N) are very large -- similar to those found in the most carbon-chain-rich regions of the Galaxy, and indicative of a non-equilibrium carbon chemistry. The observed methanol and acetaldehyde abundances indicate active grain-surface chemistry and desorption processes. The carbon-chain anions C4H⁻ and C6H⁻ were not detected and the upper limit on the anion-to-neutral ratio for C4H⁻ is less than 0.02% and for C6H⁻, less than 10%. These values are consistent with previous observations in interstellar clouds and low-mass protostars. Deuterated HC3N and c-C3H2 were detected, with fractionation ratios of about 4%, and 22%, respectively. A low c-C3H2 ortho-to-para ratio was measured, which is consistent with a molecular hydrogen ortho-to-para ratio of close to zero and implies a relatively young chemical age (less than about 10⁵ yr) for the matter surrounding Cha-MMS1. These observations show that a high level of chemical complexity can be present in star-forming gas.

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