NUCLEOBASES AND OTHER PREBIOTIC SPECIES FROM THE UV IRRADIATION OF PYRIMIDINE IN ASTROPHYSICAL ICES.
S. A. Sandford¹, M. Nuevo¹², C. K. Materese¹², NASA Ames Research Center, Moffett Field, CA 94035, USA; SETI Institute, Mountain View, CA 94043, USA

Introduction: Nucleobases are aromatic N-heterocycles that constitute the informational subunits of DNA and RNA, and are divided into two families: pyrimidine bases (uracil, cytosine, and thymine) and purine bases (adenine and guanine). Nucleobases have been detected in meteorites [1,2] and their extraterrestrial origin confirmed by isotope measurement [3]. Although no N-heterocycles have been individually identified in the ISM [4,5], the 6.2-µm interstellar emission feature seen towards many astronomical objects suggests a population of such molecules is likely present [6]. We report on a study of the formation of pyrimidine-based molecules, including nucleobases and other species of prebiotic interest, from the ultraviolet (UV) irradiation of pyrimidine in low temperature ices containing H2O, NH3, CH3OH, and CH4, to simulate the astrophysical conditions under which prebiotic species may be formed in the interstellar medium, protosolar disk, and icy bodies in the Solar System.

Experimental: Gas mixtures were prepared in a glass mixing line (background pressure ~10⁻⁸–10⁻⁵ mbar; relative proportions between components were determined by their partial pressures). Gas mixtures were then deposited on an Al foil attached to a 15-20 K cold finger and simultaneously irradiated with an H2 lamp emitting UV photons (Lyman α and a continuum centered around 160 nm). After irradiation samples are warmed to room temperature, at which time any remaining residues are recovered to be analyzed with liquid and gas chromatographies.

Results: These experiments showed that the UV irradiation of pyrimidine mixed in these ices at low temperature leads to the formation of several photo-products derived from pyrimidine, including the nucleobases uracil [7,8] and cytosine [8], as well as their precursors 4(3H)-pyrimidone and 4-aminopyrimidine [7,8]. Theoretical quantum calculations on the formation of 4(3H)-pyrimidone and uracil from the irradiation of pyrimidine in pure H₂O ices are in agreement with their experimental formation pathways [9]. In those residues, other species of prebiotic interest such as urea and the amino acids glycine and alanine are also be identified [8]. Pyrimidine derivatives containing CH₃ groups, including the nucleobase thymine, are also seen, but are made with much lower efficiencies [10], perhaps explaining why this nucleobase has yet to be identified in meteorites.