NUCLEOBASES AND OTHER PREBIOTIC SPECIES FROM THE ULTRAVIOLET IRRADIATION OF PYRIMIDINE IN ASTROPHYSICAL ICES.  S. A. Sandford1, M. Nuevo1,2, C. K. Materese1,2, and S. N. Milam3, 1NASA Ames Research Center, MS 245-6, Moffett Field, CA 94035, USA (Scott.A.Sandford@nasa.gov), 2SETI Institute, 189 N. Bernardo Ave., Ste. 100, Mountain View, CA 94043, USA, 3NASA Goddard Space Flight Center, MS 691.0, Greenbelt, MD 20771, USA.

Introduction: Nucleobases are \( N \)-heterocycles that are 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 ever been observed in the ISM [4,5], the positions of the 6.2-\( \mu \)m interstellar emission features suggest a population of such molecules is likely to be present [6]. In this work we study the formation of pyrimidine-based molecules, including nucleobases, as well as other species of prebiotic interest, from the ultraviolet (UV) irradiation of pyrimidine in combinations of \( H_2O \), \( NH_3 \), \( CH_3OH \), and \( CH_4 \) ices at low temperature, in order to simulate the astrophysical conditions under which prebiotic species may be formed in the interstellar medium and icy bodies of the Solar System.

Experimental: Gas mixtures are prepared in a glass mixing line (background pressure \( \approx 10^{-6} - 10^{-5} \) mbar). Relative proportions between mixture components are determined by their partial pressures. Gas mixtures are then deposited on an aluminum foil attached to a cold finger (15-20 K) and simultaneously irradiated with an \( H_2 \) lamp emitting UV photons (Lyman \( \alpha \) and a continuum at \( \approx 160 \) nm). After irradiation samples are warmed to room temperature, at which time the 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 photoproducts derived from pyrimidine, including the nucleobases uracil [7,8] and cytosine [8], as well as their precursors 4(3\( H \))-pyrimidone and 4-aminopyrimidine [7,8] (Fig. 1). Theoretical quantum calculations on the formation of 4(3\( H \))-pyrimidone and uracil from the irradiation of pyrimidine in pure \( H_2O \) 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 could also be identified [8]. However, no pyrimidine derivatives containing \( CH_3 \) groups, including the third nucleobase thymine, could be identified [10], suggesting that the addition of methyl groups to pyrimidine is not an efficient process [10].


Fig. 1: Pyrimidine derivatives formed after addition of OH groups from \( H_2O \) and \( NH_2 \) groups from \( NH_3 \). Photochemistry with \( CH_3OH \) is similar to that of \( H_2O \), with additional compounds such as 4-pyrimidinemethanol.