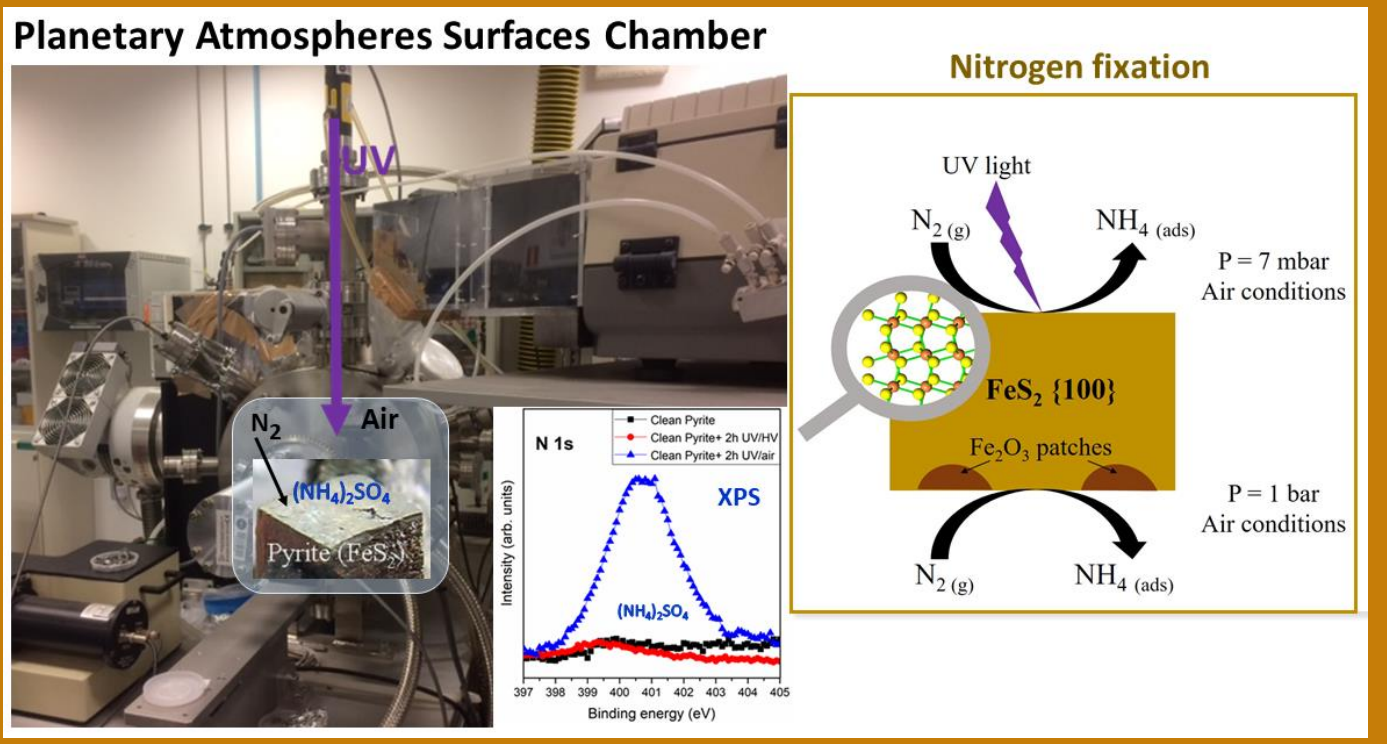
Pyrite-induced uv-photocatalytic abiotic nitrogen fixation: implications for early atmospheres and Life



PASC Chamber and XPS spectra of the presence of ammonium sulfate on pyrite surface (on the left). Schematic representation of the processes that lead nitrogen fixation on pyrite surface (on the right), (i) by UV photo-catalysis under low pressure conditions (on the top) and, (ii) by the catalytic effect of iron oxide-iron sulfide tandem under visible light conditions and standard earth atmosphere (on the bottom).

Prior to the emergence of life, there must have been an abiotic process that could fix N_2 (an essential element for life), in a biochemically usable form. The UV photo-catalytic effects of minerals such as pyrite (FeS_2) on N_2 fixation have to date been overlooked.

Here we show experimentally, using X-ray photoemission (XPS) and infrared spectroscopies that, under a standard earth atmosphere containing nitrogen and water vapour at Earth or Martian pressures, N_2 is fixed to pyrite as ammonium iron sulfate after two hours of exposure to 2,3 W/m2 of UV irradiance in the 200–400 nm range. Our experiments show that this process exists also in the absence of UV, although about 50 times slower. We conclude that UV photo-catalysis on FeS_2 may have been a natural mechanism of prebiotic fixation of N_2 into ammonium sulfates which is then easily released upon contact with liquid water.

This property of pyrite may have been incorporated naturally in the prebiotic chemistry evolution, leading to the inclusion of pyrite nano-clusters as reaction centres to generate ammonia from N_2, and then from ammonia to generate ammonium sulfates salts in the presence of oxygen. This process has critical implications for the habitability of planet and the origin of life.

E. MATEO-MARTI, S. GALVEZ-MARTINEZ, C. GIL-LOZANO AND M-P. ZORZANO, *SCIENTIFIC REPORTS*, **9**, 15311 (2019)