SUGARS AND SUGAR DERIVATIVES IN RESIDUES PRODUCED FROM THE UV IRRADIATION OF ASTROPHYSICAL ICE ANALOGS.

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Introduction: Carbonaceous chondrites contain a large variety of organic compounds of prebiotic interest, which include amino acids **[1,2]**, amphiphiles **[3,4]**, nucleobases **[4,5]**, and sugar derivatives **[7]**. The presence of these compounds strongly suggests that molecules essential to life can form abiotically under astrophysical conditions. Among the sugar derivatives reported in the Murchison and Murray meteorites **[7]**, only one sugar (dihydroxyacetone) was found, together with a variety of sugar alcohols and sugar acids containing up to 6 carbon atoms, including sugar acid derivatives of the biological sugars ribose and glucose (Fig. 1).

On the other hand, laboratory studies on the formation of complex organic molecules from the ultraviolet (UV) irradiation of simulated astrophysical ice mixtures consisting of H_2O, CO, CO_2, CH_3OH, CH_4, NH_3, etc., at low temperature have been routinely carried out in the past 15 years. These studies have shown that the organic residues recovered at room temperature contain amino acids **[8-10]**, amphiphiles **[11]**, nucleobases **[12-15]**, as well as other complex organics **[16-18]**, supporting a scenario in which molecules of prebiotic interest can form in extra-terrestrial environments.

However, until very recently, no search for the presence of sugars and sugar derivatives in laboratory residues had been carried out, despite their prebiotic significance. Several sugar alcohols, sugars, and sugar acids were first detected in residues produced from the UV irradiation of H_2O:CH_3OH ice mixtures **[19,20]**. Then ribose (the sugar of RNA) as well as several other sugars and sugar derivatives were identified in one residue produced from an H_2O:CH_3OH:NH_3 ice mixture **[21]**.

Results: In this work, we carried out a systematic search for sugars and sugar-related compounds in 15 organic residues produced from the UV irradiation of simple H_2O:CH_3OH (2:1 and 5:1) ice mixtures. We show that these residues contain sugar alcohols, sugars, and sugar acids, with up to 5 carbon atoms, including ribose and several of its isomers **[22]**. From the relative abundances of the photoproducts identified in all the residues analyzed, we also suggest that in our expriments sugar alcohols are formed before sugars, which are themselves formed before sugar acids **[22]**. This is different from the chemical pathway proposed in an independent study and which ribose and several other sugar derivatives were also identified in a residue produced from the UV irradiation of an H_2O:CH_3OH:NH_3 ice mixture **[21]**.

Finally, our results are compared with meteoritic data **[7]**. The distribution of photoproducts in our laboratory residues appears to be different from that in meteorites, in which only the smallest sugar (dihydroxyacetone) was identified, while several sugar alcohols and sugar acids with up to 6 carbon atoms are present. This suggests that the processes leading to the formation of the sugar derivatives found in meteorites are different from those simulated in laboratory experiments, and/or that other carbon sources in addition to CH_3OH are necessary to form sugar derivatives with a distribution that matches that in meteorites.

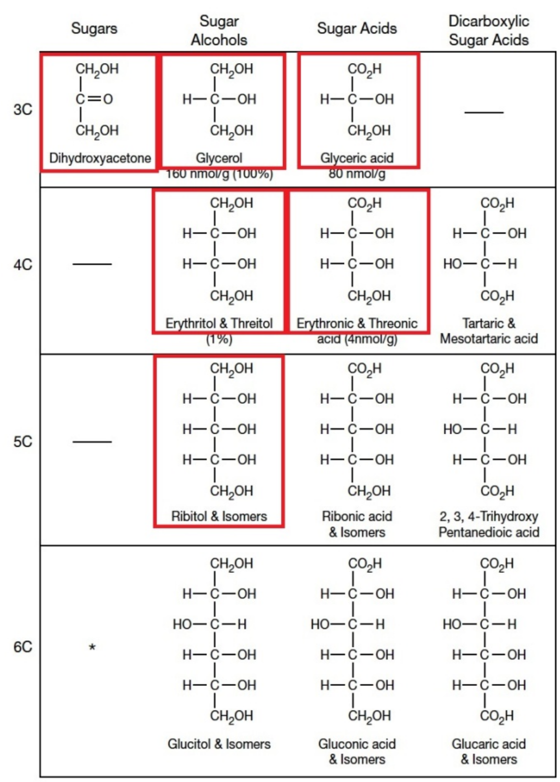

Fig. 1. *Sugar derivatives detected in the Murchison and Murray meteorites (from Ref.* ***[7]****) and that were searched for in our laboratory residues produced from the UV irradiation of H_2O:CH_3OH ice mixtures at low temperature. The red boxes indicate the compounds identified in our residues.*

References: [1] Kvenvolden K. et al. (1970) *Nature*, *228*, 923–926. [2] Cronin J. R. and Pizzarello S. (1997) *Science*, *275*, 951–955. [3] Dearmer D. W. (1985) *Nature*, *317*, 792–794. [4] Deamer D. W. and Pashley R. M. (1989) *OLEB*, *19*, 21–38. [5] Folsome C. E. et al. (1971) *Nature*, *232*, 108–109. [6] Stoks P. G. and Schwartz A. W. (1979) *Nature*, *282*, 709–710. [7] Cooper G. et al. (2001) *Nature*, *414*, 879–883. [8] Bernstein M. P. et al. (2002) *Nature*, *416*, 401–403. [9] Muñoz Caro G. M. (2002) *Nature*, *416*, 403–406. [10] Nuevo M. et al. (2008) *OLEB*, *38*, 37–56. [11] Dworkin J. P. et al. (2001) *PNAS*, *98*, 815–819. [12] Nuevo M. et al. (2009) *Astrobiol.*, *9*, 683–695. [13] Nuevo M. et al. (2012) *Astrobiol.*, *12*, 295–314. [14] Materese C. K. et al. (2013) *Astrobiol.*, *13*, 948–962. [15] Nuevo M. et al. (2014) *ApJ*, *793*, 125 (7 pp.). [16] Nuevo M. et al. (2010) *Astrobiol.*, *10*, 245–256. [17] de Marcellus P. et al. (2011) *Astrobiol.*, *11*, 847–854. [18] de Marcellus P. et al. (2015) *PNAS*, *112*, 965–970. [19] Nuevo M. et al. (2015) AbSciCon 2015, Abstract No. 7132 [20] Nuevo M. et al. (2015) ACS Fall Meeting 2015, Abstract No. PHYS 272 [21] Meinert C. et al. (2016) *Science*, 352, 208–212. [22] Nuevo M. et al., *Submitted.*