SHOCK-SYNTHESIS OF AMINO ACIDS VIA IMPACT OF COMETS AND METEORITES

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Introduction: The impact of comets onto rocky surfaces, and equally, the impact of meteorites into icy surfaces (such as some of the moons of Jupiter and Saturn) may have led to the formation of complex organic molecules through a process of shock synthesis. This may have been one of the sources of organic carbon in our solar system 4.5 to 3.8 billion years ago [1-4], just before life emerged [5-7]. Indeed amino acid precursors (such as ammonia, methanol and carbonyl compounds) have been observed in comets [8-13]. Also, the surface of Saturn's moons have IR absorption features characteristic of ammonia hydrate. Water, CO_2, ammonia and methanol have all been detected on the surface and within the plumes of Enceladus [14,15], while organic material may be present on the water ice surface of Tethys, Dione, Rhea, Iapetus, Hyperion, and Phoebe [16]. We have experimentally tested whether amino acids could be produced by shocking analogue cometary ice mixtures with a projectile fired in a light gas gun [17].

Results and Discussion: Our results show that the impact of comets onto rocky surfaces, and impacts of meteorites onto icy surfaces produces several α-amino acids, including racemic mixtures of alanine and norvaline (D/L≈1), and the non-protein amino acids α-aminoisobutyric acid (α-AIB) and isovaline [17]. This is in agreement with *ab initio* simulations modelling [18]. Suggested synthetic pathways include the Strecker-cyanohydrin synthesis using α-amino acid precursors. Alternatively, a high shock pressure would result in the formation of ions and radicals, which would then be involved in the post-shock reaction to form amino acids [18]. These results provide a realistic production pathway for the components of proteins in our Solar System, expanding the locations where life may originate.

References: [1] Chyba C. F. et al. 1990. *Science* 249: 366. [2] Chyba C.F. and Sagan C. 1992. *Nature* 355: 125. [3] Anders E. 1989. *Nature* 342: 255. [4] Furukawa Y. et al. 2009. *Nature GeoScience* 2: 62. [5] Schidlowski M. 1988. *Nature* 333: 313. [6] Schopf J. W. 1993. *Science* 260: 640. [7] Moorbath S. 2005. *Nature* 434: 155. [8] DiSanti M. A. et al. 2013. *The Astrophysical Journal* 763: 1. [9] Crovisier J. and Bockelee-Morvan D. 1999. *Space Science Reviews* 90: 19. [10] Ehrenfreund P. et al. 2002. *Reports on Progress in Physics* 65: 1427. [11] Ehrenfreund P. and Charnley S.B. 2000. *Annual Review of Astronomy and Astrophysics* 38: 427. [12] Mumma M. J. et al. 2003. *Advances in Space Research* 31: 2563. [13] Bockelee-Morvan D. et al. 2000. *Astronomy and Astrophysics* 353: 1101. [14] Waite J. H. et al. 2009. *Nature* 460: 487. [15] Brown R. H. et al. 2006. *Science* 311: 1425. [16] Ostro S. J. et al. 2006. *Icarus* 183: 479. [17] Martins Z. et al. 2013. *Nature Geoscience* 6: 1045. [18] Goldman N. et al. 2010. *Nature Chemistry* 2: 949.