Delivering prebiotic feedstocks with cometary impacts

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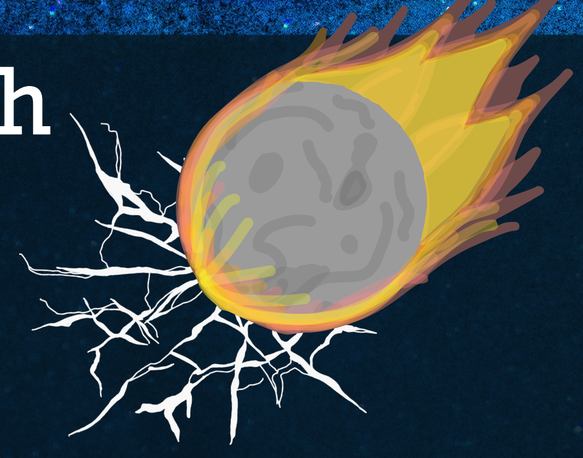
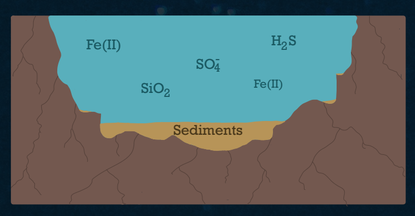
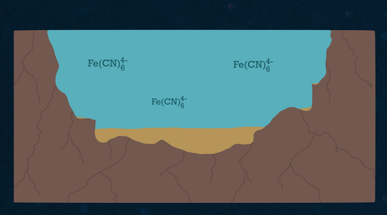


Delivery scenario

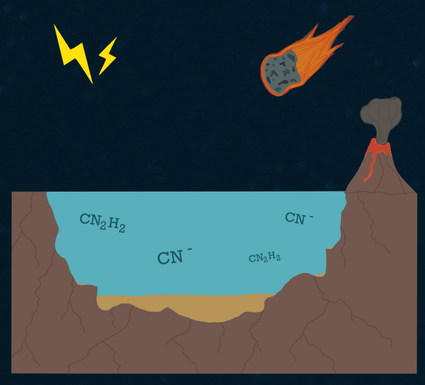
One particular scenario for the origins of life on the early Earth invokes cometary delivery in the following way[2]…



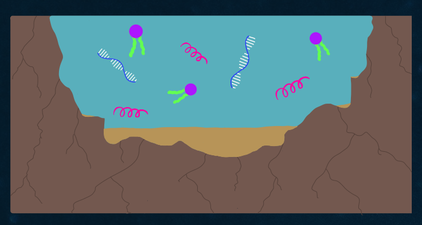
An isolated body of water with important molecules…



…is impacted by a comet which delivers hydrogen cyanide (HCN).



Additional energy activates the cyanosulfidic pathway to life…



…which leads to the formation of RNA, lipid and protein precursors[1].

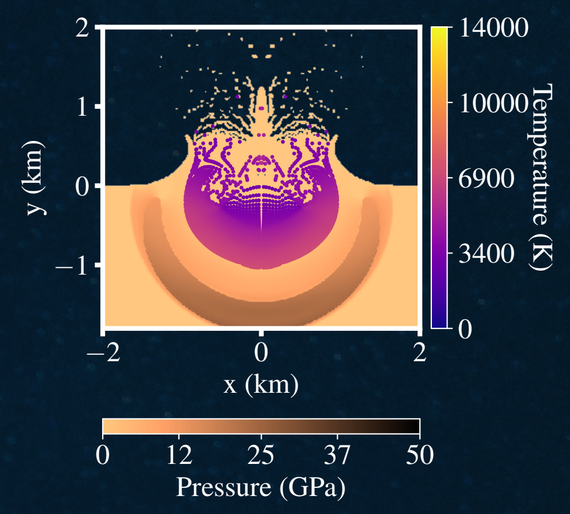
This work aims to determine how effective cometary impacts are at delivering HCN.

Methods

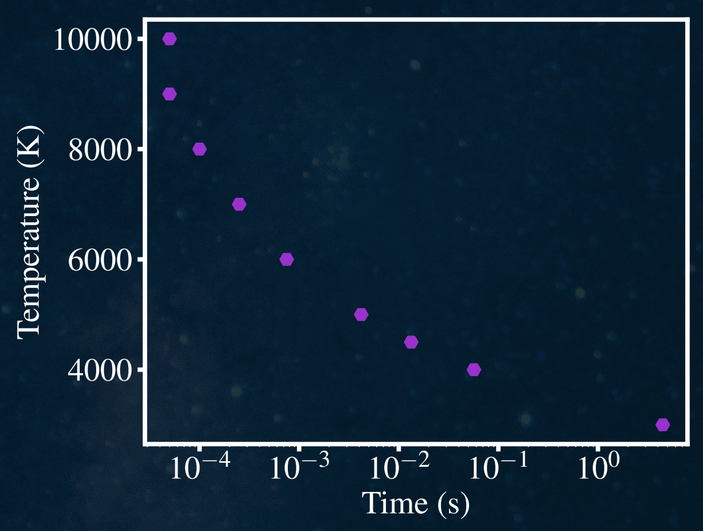
Impact simulations

iSALE

- iSALE grid-based hydrocode
- Spherical comet made of pure water ice with a homogeneous HCN distribution
- Solid basalt impact site to simulate surface of early Earth



A simulated impact of a 1km comet hitting the surface of the early Earth with v_{imp} = 20 kms^{-1}. The temperature data traces the material of the comet.



The time taken for 99% of HCN to degrade at different temperatures with our simple chemical model.

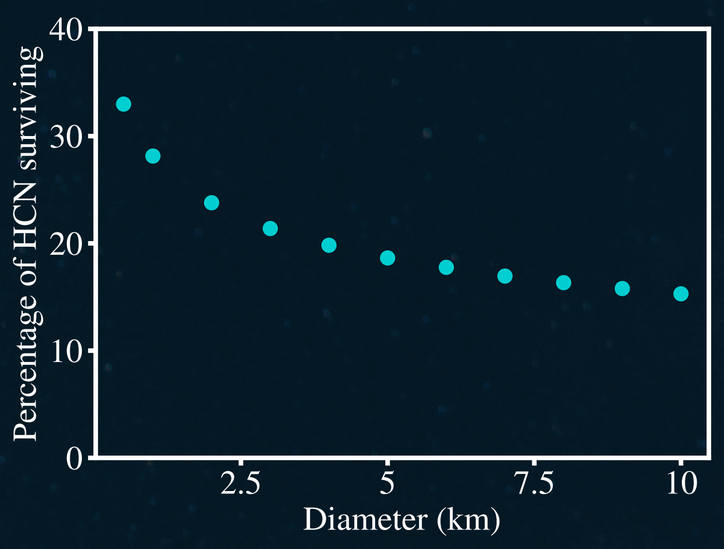
Chemical Modelling

- Simple model:
  - Thermal decomposition of H_2O
  - Radical driven destruction of HCN

Which cometary impacts are most efficient at delivery?[3,4]

Small…

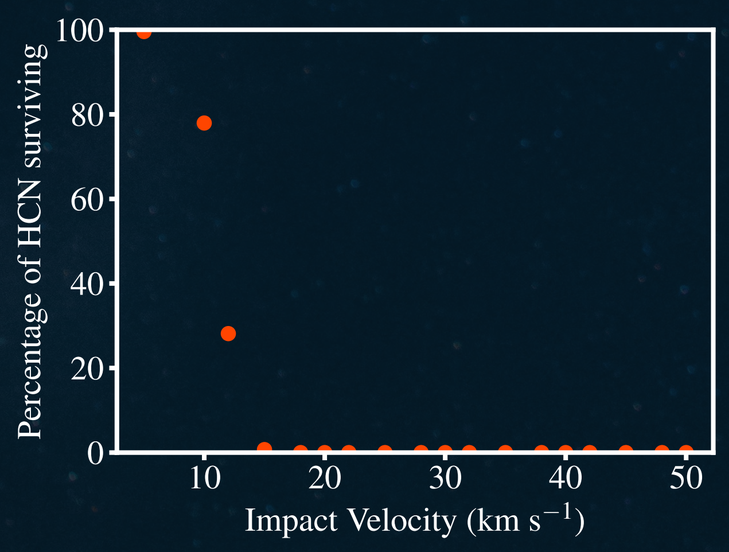
The impact shockwave passes through smaller bodies quicker, reducing the time the material stays at high temperatures, boosting HCN survival.



The percentage of HCN which survives an impact at v_{imp} =12 km s^{-1} for a range of impactor diameters.

…slow…

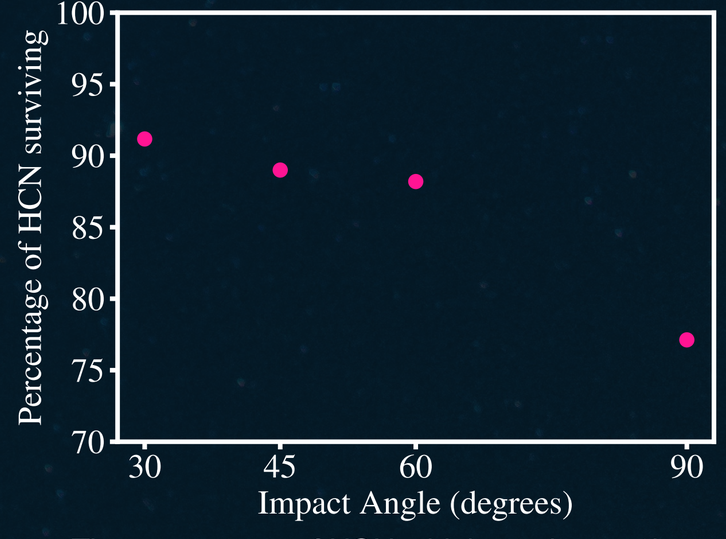
Higher impact velocities increase the temperatures experienced by the cometary material, efficiently destroying HCN.



The percentage of HCN which survives a 1km diameter comet impacting at a range of impact velocities.

& oblique.

Oblique impacts reduce the temperature experienced by the cometary material increasing HCN survival.



The percentage of HCN which survives a 1km diameter comet impacting at 10 km s^{-1} for a range of impact angles.

References

[1] Patel et al., 2015. Nature Chemistry 7, 301–307. doi: 10.1038/nchem.2202
[2] Sasselov, Grotzinger, & Sutherland, 2020. Science Advances 6, eaax3419. doi: 10.1126/sciadv.aax3419
[3] Pierazzo & Chyba, 1999. Meteoritics & Planetary Science 34, 909–918. doi:10.1111/.1945-5100.1999.tb01409.x
[4] Todd & Öberg, 2020. Astrobiology 20, 1109–1120. doi: 10.1089/ast.2019.2187

Scan here to see successful and unsuccessful impacts!

Background image: Nicole Avagliano