Simulating impacts onto Earth: from enabling early life to causing extinction

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The history of our planet is intimately tied to the effects of impacts, from the giant collision that formed the Moon to the asteroid that devastated the dinosaurs, and many more besides. New supercomputing tools [1,2] allow us to study these events in unprecedented detail to tackle many unsolved mysteries [e.g. 3; Fig. 1].

One of these mysteries is how the atmospheric and surface environments that enabled the formation of prebiotic organic compounds came to be. In particular, the iron delivered from the cores of large impactors towards the end of Earth's accretion has been suggested to help to generate the highly chemically-reduced environment that was needed to form RNA precursors [4,5]. However, many open questions remain, and previous simulations have been limited in their resolution and material properties (Fig. 2). The aim of this project is to use state-of-the-art tools to model large impacts onto the early Earth in far finer detail than previously possible, to examine the fate of impactor material and the implications for the atmosphere, mantle, and conditions for life.

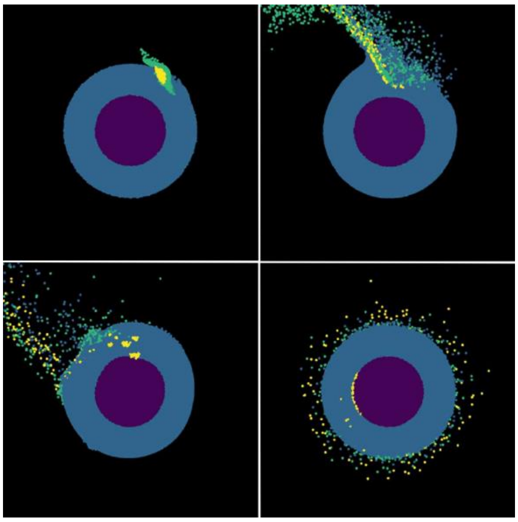

Fig. 2: A previous, standard-resolution SPH simulation of an iron-delivering impact [5].

Conversely, a large enough impact could be harmful for life. At the most extreme end, melting of the entire upper mantle could erase life all together, while the Chicxulub crater-forming impact is thought to have caused the decade-long winter that caused the extinction of ~75% of all species, including the non-avian dinosaurs, by ejecting debris into the atmosphere [6,7]. But how do the harmful effects of an impact scale with its size, and when does an impact become an extinction-level event? This poorly understood question could also tie into considerations for planetary defence and, for example, the DART and HERA missions that are exploring how to prevent hazardous asteroids from colliding with Earth [8].

Given the many open questions that could be explored around these impactful topics, the candidate will be free and encouraged to pursue new directions with their research beyond

Fig. 1: Two snapshots from a high-resolution SPH simulation that opened up new options for the Moon-forming impact [3]. The impactor's core is also drawn into a long stream that falls into Earth's mantle.

these initial projects. Depending on the candidate's interests, this includes various opportunities for them to lead major new contributions to the development of cutting-edge simulation codes used by researchers around the world.

The successful candidate will join, and be supported by, a vibrant and dynamic research group with world-class expertise modelling impact processes. They will be trained in state-of-the-art numerical methods for simulating impacts, impact physics, and high-performance computing. The candidate will have the opportunity to develop their career and profile by presenting at international conferences and publishing in high impact journals. Candidates for PhD positions should have a good mathematical background and a good degree in an appropriate field, such as physics, earth science, mathematics, or computer science.

Supervision

Dr Jacob Kegerreis is an expert in impact simulations and is the lead planetary developer of the SWIFT code.

Prof Gareth Collins is an expert in impact physics and modelling geophysical processes.

Dr Vincent Eke is an associate professor at Durham University and an expert in planetary modelling.

Research Environment & Training

The Department of Earth Science and Engineering (ESE) is an STFC-accredited PhD training program. The Department is well-equipped with modern laboratories, offices and high-performance computing facilities. It also benefits from a formal collaboration (facilities and staff access; joint symposia) with colleagues in the Department of Mineralogy at the Natural History Museum (NHM). Project-specific research training will be provided by the supervisors through weekly one-to-one meetings, group meetings, and a mixture of supervised and online tutorials. In addition, students have access to high-quality transferable skills training provided by the Graduate School of Engineering and Physical Sciences (GSEPS). All students in ESE are automatically members of GSEPS. The Postgraduate programme involves regular report writing and presentation events in addition to research section and research group presentations. Students are strongly encouraged and enabled to attend international conferences and publish their work in respected journals.

References

[1] Kegerreis et al. 2019, MNRAS 487, 1536.
[2] Schaller et al. 2024, MNRAS 530, 2378.
[3] Kegerreis et al. 2022, Astrophys. J. Lett. 937, L40.
[4] Zahnle et al. 2020, Planet. Sci. J. 1, 11.
[5] Citron and Stewart 2022, Nat. Geo. 3, 116.
[6] Collins et al. 2020, Nature Comm. 11, 1480.
[7] Senel et al. 2022, Nature Geo. 16, 1033.
[8] Raducan et al. 2024, Nature Astron. 8, 445.

For more information on the variety of potential research projects that could be pursued, see our group animations and webpages for examples of previous projects, or contact us by email: www.youtube.com/@jkeger_et_al, astro.dur.ac.uk/~cklv53/, www.imperial.ac.uk/earth-science/prosp-students/phd-opportunities/project-topics/planetary-science/