Modelling the Giant South Pole-Aitken basin

Professor Gareth Collins (g.collins@imperial.ac.uk)

The ~2500-km diameter South Pole-Aitken (SPA) basin is the oldest and largest known impact structure in the Solar System. The effects of this giant impact event on the Moon were profound. The crater dominates the topography, crustal structure, subsurface density distribution and surface composition of the farside of the Moon [1-3], and the South Pole—the destination of NASA's Artemis III mission that aims to return humans to the Moon by 2024. Proposed consequences of this impact include exposure of the Moon's upper mantle in the proximal ejecta and basin interior [4], the origin of lunar magnetic anomalies by deposition of iron-rich impactor material [5], and formation of a deep-seated and long-lived fracture network on the nearside (SPA antipode) that facilitated magma ascent [6] or even triggered volcanism [7]. Understanding the SPA basin-forming impact is key to unlocking much of the Moon's history and evolution and is a major objective of the Artemis III mission [8].

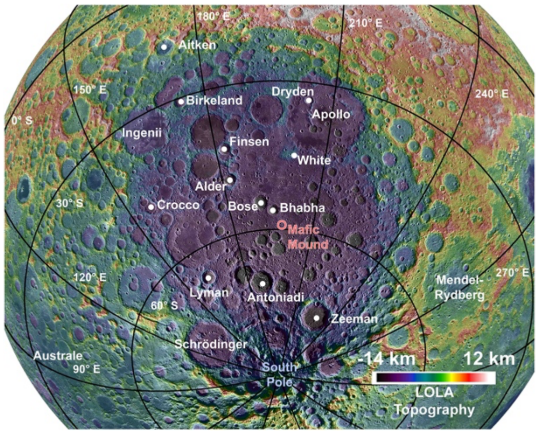

Figure 1 *The South Pole-Aitken (SPA) basin is the oldest and largest known impact structure in the Solar System. The effects of this giant impact event on the Moon were profound. Figure from [2].*

Previous 2D numerical simulations of the SPA impact [9] showed that its consequences are sensitive to the thermal state of the Moon at the time of impact and hence how soon after the Moon's formation the collision occurred. Those simulations determined the likely impact energy, maximum depth of excavation, melt production and final surface distribution of crustal and mantle materials under the simplifying assumption of a vertical impact. SPA's elliptical planform and asymmetric surrounding topography, however, imply that the impact was oblique, with a trajectory approximately south to north [1]. While some pioneering three-dimensional oblique impact simulations of the SPA impact have been performed [4-6], an authoritative investigation of the consequences of the impact, and their sensitivity to impactor and target properties, is lacking.

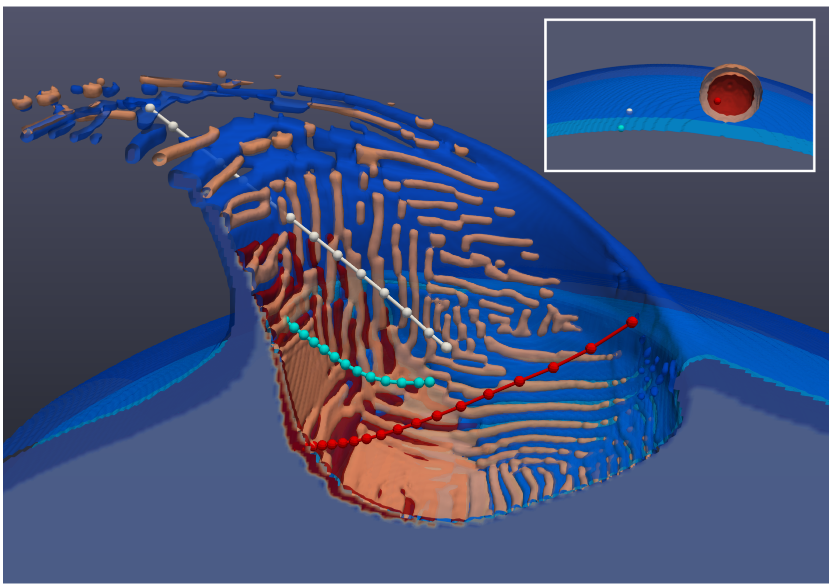

Figure 1: *iSALE3D simulations of oblique impacts on Earth and moon-like layered targets will reproduce key observations of the South Pole-Aitken basin, such as its size and shape. Simulations will track ejecta and impactor material to inform understanding of the consequences of the event. Target material ejected at high speed (white/blue tracers) will be tracked to tracked to determine the provenance of compositional anomalies in and around the SPA basin; and impactor core material (red) will be tracked to constrain impactor-target mixing.*

The aim of this project is to conduct a comprehensive modelling study of the SPA impact that includes a compositionally distinct crust and considers a range of preimpact temperatures, impactor speeds and impactor compositions. The work will determine how cratering has mixed and deformed the original crustal and mantle rocks—a key Artemis III objective—which is vital for interpreting SPA's compositional and density anomalies, the composition of the upper mantle, the origin of the Moon's magnetic anomalies, and possible implications for antipodal magmatism.

While the SPA-basin impact is uniquely large among the confirmed craters on the Moon, the much greater size and gravity of Earth implies that it likely experienced a few tens of impacts of similar magnitude during its earliest post-moon-formation history. With limited evidence preserved in the geological record, the consequences of this violent period of Earth's history are poorly understood [10]. Thus, we will also simulate SPA-scale impacts on Earth to address important unresolved questions such as the fate of impactor core material and how efficiently the impact process mixes the impactor core with Earth's mantle.

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 hypervelocity impact, 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 earth science, physics, mathematics or computer science.

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] Garrick-Bethell I, Zuber MT. (2009) Icarus 204:399–408. [2] Moriarty DP, Pieters CM. (2018) JGR-Planets 123:729–47. [3] James PB, et al. (2019) GRL 46:5100–6. [4] Melosh HJ, et al. (2017) Geology 45:1063–6. [5] Wieczorek MA, et al. (2012) Science 335:1212–5. [6] Schultz PH, Crawford DA. (2011) GSA Spec. Pap. 477:141–59. [7] Kring DA, et al. (2015) LPI Contribution 1826:3009. [8] Artemis III Science Definition Team Report, NASA/ SP20205009602. [9] Potter RWK et al. (2012) Icarus 220:730–43. [10] Marchi S, et al. (2014) Nature 511:578–82.