Giant impacts and the origin of planetary atmospheres  
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Project Background:
How the Earth acquired its unique atmosphere and oceans is one of most fundamental, unanswered questions in Earth science. Earth is thought to have inherited most of its current inventory of water, and potentially a significant fraction of its other volatile elements (such as C, N, and the noble gases), from before the Moon-forming impact which marked the end of the main stage of Earth’s accretion. A fraction of the volatile elements delivered to Earth must therefore have survived the violent events of accretion, including collisions between the growing planets and the bombardment of radiation and particles from the active young sun. The competition between the mechanisms of volatile delivery and loss is also potentially responsible for producing the wide range of atmospheric masses and compositions we see in our solar system, and in exosystems, today.

The last stage of the main phase of terrestrial planet formation is thought to involve collisions between planet-sized bodies, so-called giant impacts (Figure 1). Giant impacts are the most energetic event planets experience during their formation and can eject varying amounts of the atmospheres, oceans, crusts, mantles and cores of the colliding bodies. The large amount of energy dissipated in an impact and the massive torque exerted by the impactor can leave the post-impact body rotating rapidly and substantially melted and vaporized. Critical for understanding the origin of planetary atmospheres is quantifying how efficient giant impacts are at delivering and removing volatiles from the colliding bodies. Recently, huge strides have been made in this area with high-resolution giant impact simulations that can directly trace the fate of increasingly thin atmospheres (e.g., Kegerreis et al 2020a,b; Figure 1).

However, there are still aspects of how giant impacts shape planetary atmospheres that are not understood. For example, the gravitational interactions between colliding bodies as they approach each other leads to disruption of the atmospheric structure and redistribution of the atmosphere and ocean across the surface of the bodies, changing the susceptibility of the atmosphere and ocean to loss, an effect that has not been considered in previous work. In addition, the volatiles that remain bound to the hot post-impact body are dissolved into the silicate vapor, but the process by which a volatile-dominated atmosphere emerges after the impact has not been studied. Understanding such processes is key to elucidating the origin of the atmospheres and oceans of terrestrial planets.

Figure 1: A smoothed particle hydrodynamics (SPH) simulation of a grazing impact between two bodies with masses of 0.887 and 0.133 Earth masses, respectively, where the larger body has a 0.1 Earth mass atmosphere. Figure from Kegerreis et al. (2020a).

Project Aims and Methods
This project aims to quantify the role that impacts play in the origin of the atmospheres of terrestrial planets. The successful applicant will use a mixture of analytical calculations and state-of-the-art hydrodynamic and multi-physics simulations to determine how efficiently volatiles are lost during collisions, incorporating the effects of pre-impact rotation and redistribution of the atmosphere and ocean. The
optimal outcome would be to develop a ‘scaling law’ that predicts the amount of atmosphere and ocean lost given the parameters of the impact and the initial surface conditions (see e.g., Denman et al., 2020; Kegerreis et al., 2020b). The second part of the project will consider what happens to the volatile elements that are bound to the surviving bodies after the impact and determine how the atmosphere and ocean emerge as the post-impact body cools. The scope of this project is broad, and the successful applicant will be able to direct the research to match their specific interests and skills. The project will make extensive use of the high-performance computing facilities at the University of Bristol and national supercomputing facilities.

**Candidate**
The successful applicant should have a keen interest in Earth sciences, planetary sciences or astrophysics and a background in a related physical science or computer sciences. We particularly welcome applications from people from minoritized groups, such as members of the LGBT+ and BAME communities, and/or with non-traditional career paths.

**Training**
Through the project the student will become familiar with a broad range of topics in the Earth and planetary sciences and be introduced to the national and international research communities. Dr Lock is an expert in the use of numerical simulations to solve planetary science problems and will provide training in the design, development, and running of a range of numerical codes, including hydrodynamic planetary impact and planetary structure codes, and the analysis of the output from such simulations. The results of the project will be communicated in peer-reviewed publications, talks, and poster presentations, and the student will be encouraged to develop their communication skills through courses offered through the university's Personal and Professional Development programme. The student will also have the opportunity to develop other professional skills such as project management, networking, and mentoring.

**Background reading**
All these papers should be available free of charge from the publisher’s website, but I have also given links to pre-print versions when available, just in case. If you cannot access these papers for any reason, please contact Dr Lock.


**Eligibility:** It is possible to award non-UK residents with an STFC PhD training grant, but special conditions apply and a fee waiver by the University is required which is not guaranteed.

**Application deadline:** 23.59 GMT, 10th Jan 2022

Apply to the University of Bristol: [http://www.bristol.ac.uk/study/postgraduate/apply/](http://www.bristol.ac.uk/study/postgraduate/apply/).

Please select PhD in Geology as the programme in the online application system.