The role of giant impacts in the formation of the outer solar system and exosystems
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Project Background:
Giant impacts (collisions between planet-sized bodies) are the most violent events in planet formation. For a few hours, collisions that form greater than Earth-mass bodies release more energy than the Sun. Large fractions of the icy and/or rocky mantles of the colliding bodies are melted and vaporised, and the huge torques exerted can leave the post-impact body rapidly rotating. The mass of the largest body may either increase or decrease, depending on the amount of material ejected from the system. Impacts can fundamentally alter the trajectory of a planet’s evolution, as the ratios of atmosphere, crust, mantle and core all change and systems of moons can be formed. For example, giant impacts are thought to be responsible for the high obliquity of Uranus, the high density of Mercury, and the formation of Earth’s Moon.

The thermal and rotational states of post-impact bodies are so extreme that a significant fraction of impacts produce synestias, a recently theorised class of planetary object (Lock & Stewart, 2017). Synestias are bodies that exceed the corotation limit, defined as the angular momentum at which a planet’s equatorial velocity equals that of a circular Keplerian orbit. Post-impact synestias are typically many times larger than cooler planets and form donut-shaped structures (Figure 1). The different dynamical and thermodynamical states of synestias have significant implications for moon formation, core formation, and the distribution of volatiles within planets.

Only a limited record of giant impacts remains in our solar system, but exoplanet observations are revolutionising this field. Recent space telescopes, such as Kepler and TESS, along with multiple ground-based surveys, are dramatically increasing the number of known exoplanets. Exosystems have a range of architectures and host planets with widely varying densities, and so bear witness to the many possible outcomes of giant impacts and planet formation in general. Furthermore, as we find more and more exoplanets and begin to observe planets around younger stars, we may soon detect planetary bodies in the immediate aftermath of giant impacts.

Studies of giant impacts, with which these observations are interpreted, have largely focused on the impacts expected during formation of our inner solar system. There has been little work on collisions between more massive planets, even though such impacts could have helped shape the outer solar system. In addition, ours may not be a typical planetary system. It lacks the most common planets found around other stars: super-Earths and mini-Neptunes (planets with radii between Earth and Neptune). Many of these planets have large ice (e.g., water) and/or gas fractions. Few studies have explored impacts between more massive terrestrial and/or volatile-rich bodies and, at present, we do not understand the outcome of what are likely the most frequent planetary collisions in the universe.

Figure 1: A graphical artist’s rendition of a terrestrial synestia (Ron Miller, Scientific American, 2019). The post-impact structure has an equatorial radius more than ten times the radius of the pre-impact planet. The silicate gas that makes up the outer regions of the structure is condensable, and the radiative surface is marked by clouds of silicate rain radiating at ~2300K.

Project Aims and Methods
This project will explore how collisions shape the planets in our solar system and in exosystems. Using state-of-the-art giant impact simulations, the successful candidate will investigate the
range of dynamic and thermodynamic outcomes of collisions between water-rich bodies, and develop ‘scaling laws’ that relate the outcomes to the impact parameters. Although generally a common occurrence, the rates and energies of impacts vary between different planet formation models. By analysing the frequency and parameters of impacts in each scenario, the student will ascertain how giant impacts would sculpt planetary systems in different cases. Furthermore, by determining the observational signatures of post-impact bodies and synestias, the project will aim to provide the tools necessary to identify synestias, and other post-impact bodies, in other solar systems.

**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 astrophysics and be introduced to the national and international research communities. Dr Lock and Dr Leinhardt are experts 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 preprint 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.