IMPERIAL

Simulating impacts onto Saturn's icy moons and rings

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Saturn hosts a remarkable and diverse system of rings and moons that have provoked many long-standing open questions. The mid-sized icy moons interior to Titan, Saturn's largest moon, and the rings themselves are now thought to have formed as recently as a few hundred million years ago [1], perhaps as the result of a collision in a precursor system [2] (Fig. 1). Impacts of various scales continue to play key – but poorly understood – roles in the system's evolution.

One of the many unusual features of these icy moons is their distribution of craters, which suggest a population of lower-speed impactors from within the Saturnian system, in comparison with the distribution seen elsewhere that would be produced by higher-speed impactors from orbits around the Sun [3; Fig. 2]. However, the relationship between crater size (and shape) and impactor properties (size and speed) has been well studied only for rocky bodies and is lacking for icy bodies. Saturn's moons are mostly ice, and some like Enceladus are home to a sub-surface ocean [4], making them key targets for future missions. The first aim of this project is to use state-of-the-art supercomputer simulations [5,6] to model impacts onto icy moons, to examine in unprecedented detail the sizes and shapes of craters produced and the implications for the internal evolution and the inferred surface ages of Saturn's icy moons.

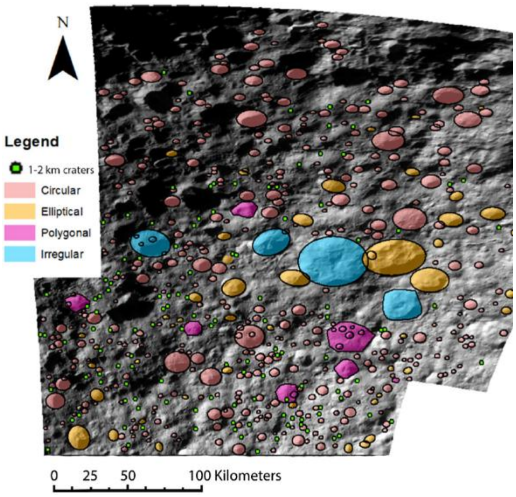

Fig. 2: Craters on Tethys, with a distribution that suggests a contribution from planeto- rather than helio-centric impactors [3].

The young age of Saturn's rings is implied by the combination of three key observations from the Cassini mission [1]: their low mass; the very low fraction of non-icy "polluting" material; and the incoming flux of micrometeoroids. These micrometeoroids bombard ring particles, eroding and polluting them [7]. However, the details of this process are poorly understood, and the efficiency of erosion and darkening with non-ice material has not yet been determined. Furthermore, the very high speeds (~30–70 km/s) that are typical for these impacts have so far prohibited any direct lab experiments. The goal

Fig. 1: Two snapshots from an SPH simulation of a collision between two icy moons [3], scattering ice and rock debris that could evolve into the rings and disrupt, re-form, and eventually crater the moons.

of this ambitious project is to simulate collisions of hypervelocity micrometeroids with ring particles, to reveal the implications for the age, history, and ongoing evolution of Saturn's iconic rings.

Given the many open questions that could be explored around these topics, the candidate will be free and encouraged to pursue new directions with their research beyond these initial example 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 strong mathematical background, proven aptitude for scientific programming, 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 Paul Estrada is a research scientist at NASA Ames and an expert in the Saturn system and ring evolution.

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] Kempf et al. 2023, Science Adv. 9, 19.
[2] Teodoro and Kegerreis et al. 2023, Astrophys. J. 955, 137.
[3] Ferguson et al. 2022, J. Geophys. R. Planets 127, 6.
[4] Iess et al. 2014, Science 344, 6179.
[5] Kegerreis et al. 2019, MNRAS 487, 1536.
[6] Schaller et al. 2024, MNRAS 530, 2378.
[7] Durisen and Estrada 2023, Icarus 400, 115221.

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/