Suggested title of dissertation:

Can outgassing make comets deviate from Newtonian orbits?

Dissertation supervisor:

Prof Sam Howison

Description of the proposal:

In 2017 the small space object named Oumuamua was observed to cross the Solar Syatem at an inclination to the plane of the ecliptic (the planets, asteroids and most comets are close to this plane, which is approximately normal to the rotation axis of the Sun). Oumuamua has since been observed to leave the solar System faster than it would under if subject to Newtonian gravitational forces. It is conjectured that this is due to 'outgassing': the ejection of gas as the sun's heat warms the body. The project will entail: (i) reviewing the literature on modelling of outgassing (ii) building a simple model for a spherical body, to include rotation and the effect of some delay (due to heat conduction) in outgassing; (iii) analysis of the model using techniques of perturbation analysis.

Possible avenues of investigation:

1. Review history and literature of Oumuamua.
2. Review models of outgassing (entails a guided literature search) and select a relevant ome; if there is no such, then formulate a simple model based on a simple energy balance (absorbed solar radiation becomes heat and produces gas which, by carrying momentum away from the body, produces a normal force; it may be necessary to model the heat-flow inside the solid by a 1-D heat equation).
3. There are then various aspects to look at:
   (a) Model the effect of a small force away from the sun on a body in a hyperbolic orbit (regular perturbation expansion). Here the force is still central (parallel to gravity).

(b) Establish whether a rotating spherical body can experience a non-central force (because the rotation carries the heated surface area away from the body-sun line before outgassing ceases); Calculate its dependence on the parameters of the problem.

(c) Apply b to see whether a rotating body can change the plane of its orbit.

(d) Apply either of the above to a body in elliptical orbit to see the effect of a small force over multiple orbits (method of multiple scales).

(e) Something we haven't thought of yet.

Pre-requisite knowledge:

A familiarity with Newtonian planetary dynamics, heat conduction and related thermal physics and basic perturbation theory, This is a modelling project and the student will need to feel comfortable building new models and simplifying them (for example using dimensionless parameters) as well as some numerical work.

Further references:

Marco Micheli et al., Non-gravitational acceleration in the trajectory of II/2017/U1 (Oumuamua). letters to Nature `https://doi.org/10.1038/s41586-018-0254-4` (2018)