Planetary atmospheres: observing Titan’s chemistry and dynamics

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Fig 1: Image of Saturn’s largest moon, Titan from Cassini’s ISS camera. Titan’s thick atmosphere is often used as an early-Earth analogue. A south polar cloud is visible near the image centre, coinciding with Titan’s polar vortex. [NASA/JPL]

Fig 2: Example thermal infra-red spectrum of Titan from Cassini’s CIRS spectrometer, which measured over a terabyte of data during the mission (2004-2017). Observations of the gas emission peaks can be used to determine atmospheric composition and temperature. These results can be used to probe atmospheric chemistry and dynamics, providing insight into the workings of Titan’s atmosphere.

Project Background
Titan is the largest moon of Saturn and is the only moon in our solar system with a substantial atmosphere, composed of nitrogen, methane and a host of trace organic species. In many ways Titan is a miniature version of Earth, but under much colder conditions and with an exotic atmospheric composition. Many atmospheric processes occurring on Earth have analogues on Titan, including polar vortices, large-scale atmospheric circulation, photochemistry, polar night radiative cooling, cloud formation, and rainstorms. For example, Titan’s stratospheric organic hazes and trace gases play a similar role to Earth’s ozone layer. Studying Titan’s atmosphere is fascinating in its own right, but also provides a natural laboratory for probing fundamental atmospheric chemical and dynamical processes. These processes are also important for understanding Earth’s atmosphere and those of many other planets in the Solar System and beyond.

Project Aims and Methods
This project will study dynamical and chemical processes in Titan stratosphere and mesosphere. In particular, extreme planetary-scale winds (jets) and mixing processes between polar and mid-latitude air masses. These processes control much of the large-scale seasonal changes occurring on Titan and are fundamental to understanding its climate. Atmospheric features will be studied using infra-red spectroscopic observations from orbiting spacecraft (Cassini), space telescopes (James Webb), and ground-based observatories (ALMA). There will also be opportunities to propose additional new telescope observations during the PhD. Spectra will be analysed using radiative transfer methods and inverse theory techniques to recover atmospheric properties that best fit observations and existing constraints. The derived physical and chemical atmospheric state can then be used to develop interpretations of atmospheric circulation, photochemistry, and seasonal evolution. Minor organic chemical species are particularly interesting as they act as tracers of atmospheric circulation and can be used to probe winds and air mixing. There will be opportunities for the student to guide the project direction, in particular during data analysis and interpretation or in proposing new observations.
Spacecraft data analysis will comprise the bulk of the project, led by the main supervisor (Dr Teanby). To help interpret observed atmospheric features, results will be compared to theoretical predictions and numerical planetary climate models adapted from studies of the Earth’s atmosphere, which are currently under development by members of the supervisory team (Dr Seviour and Dr Mitchell). These observation-theory-model comparisons will allow more complete understanding of Titan’s atmosphere and will potentially feed back into our understanding of fundamental climate physics. Results will also inform the next generation of space missions such as the Dragonfly nuclear-powered drone mission to Titan.

**Candidate**

Ideally a background in physics- or mathematics-based subjects to MSc/MSci level. A strong interest in space exploration, planetary science, atmospheric physics, and data analysis techniques is essential. Familiarity with scientific computing/programming would be an advantage as the major component will be quantitative analysis of spectroscopic datasets using both existing code and new code developed by the student.

**Training**

Skills will be built up via independent study and one-to-one supervision but could also include attendance of specific lecture courses and workshops (as required). There is also expected to be opportunities to visit collaborators at NASA Goddard Space Flight Centre, Johns Hopkins University, or the Space Telescope Science Institute during the project. The student will present results at national/international conferences, interact with national/international collaborators, and publish findings in high impact scientific journals. This will require excellent communication and written skills. The project will also require development of skills in atmospheric and planetary science, remote sensing, radiative transfer, inverse theory, and numerical analysis. This will leave the student in an excellent position for a career in atmospheric/planetary science, or any field requiring numerical data analysis.

**References / Reading List**


JWST Mission: [https://www.jwst.nasa.gov](https://www.jwst.nasa.gov)

ALMA Telescope: [http://www.alma.science.org](http://www.alma.science.org)

**Eligibility:** STFC PhD training grant funding is limited to UK resident students.

**Application deadline:** 23.59 GMT, 1st Feb 2021

How to 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.