

## Using the Met Office Unified Model and UKCA to study the Earth's Phanerozoic atmosphere as an analogue for Earth-like exoplanets.

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### Project Background

Up until a few decades ago we were limited to studying planets within our solar system. Technological advances allow us to observe extrasolar planets (exoplanets) that orbit stars other than the Sun. To date more than three thousand exoplanets have been confirmed with a longer list of candidates that await confirmation. Out of these confirmed cases, only a small number are considered potentially habitable from the Earth-centric perspective.

Why are these important discoveries in the context of Earth sciences? The size of detected exoplanets and the distance from their host stars challenge our understanding of planetary formation that has until recently been exclusively derived from the size and location of solar system planets. Detection of exoplanets therefore has potential implications for our current understanding of the formation of Earth and its atmosphere. We are also beginning to detect Earth analogues (planets similar to Earth, e.g., Proxima Centauri b) that potentially represent the surface and atmospheric environments of Phanerozoic Earth. This period on Earth is associated with the emergence of complex multicellular organisms that eventually changed the chemical composition of the global atmosphere. Consequently, studying exoplanets offer us an opportunity to better understand the evolution of early Earth.

For our exploration of the atmosphere of Phanerozoic Earth we will use a generalized 3-D planetary simulator (GPS) that shares its dynamical core with the Met Office Unified Model (UM), which is used more typically for weather and long-term climate prediction. GPS is maintained through a Met Office Academic Partnership with the University of Exeter. In ongoing work, we are integrating the UK Chemistry and Aerosol (UKCA) model, also maintained as a component of the UM, with the GPS. Exploring the atmosphere of Phanerozoic Earth provides rigorous tests for the UM atmospheric dynamics and UKCA. We will use a radiative transfer model to describe the spectral signatures of gases on early Earth. If intelligent life looked at Phanerozoic Earth from afar would they be able to detect the existence of biological life by looking at variations in atmospheric radiation?

### Key research questions

Here, we propose two ambitious and overarching research questions that could each be the focus of the PhD project, depending on the qualifications of the successful applicant:

- 1) Do space-time variations of the physical and chemical environment improve our ability to interpret future spectral observations of exoplanetary atmospheres?
- 2) Does the composition of atmospheric aerosol, clouds and other scattering surfaces improve the detectability of hypothetical atmospheric signatures of biological life?

## Methodology

The proposal is underpinned by two major research initiatives that are mature enough to form a coherent PhD project. First is the development and evaluation of the GPS by the UK Met Office and the University of Exeter. The GPS is currently being used to study Hot Jupiters, Jupiter-sized planets that are extremely close to their host star, and Earth-like terrestrial planets that are closer to the size of Earth but orbiting a star with a luminosity different from the Sun. Second is the UKCA model, which includes a comprehensive description of atmospheric chemistry of gases and aerosol particles. UKCA has so far been applied so far only to study Earth's atmospheric composition so that applying it with other planetary constraints provides a useful test of its robustness. The LIDORT radiative transfer model will determine the atmospheric spectra that might be observed from future telescopes.

## Training

As part of the E3 DTP and via the supervisory team you will receive a comprehensive training programme that includes specialist scientific training and generic transferable and professional skills. You will also become a member of the new Centre for Exoplanet Science at the University of Edinburgh. Specialist training will include: (1) exoplanetary atmospheric science, and (2) computer modelling for simulating global 3-D atmospheric chemistry. The training required to run the GPS and UKCA is provided by the Met Office.

## Requirements

The successful candidate will have a degree in the physical sciences and most likely physics, chemistry, or applied mathematics. This is a computational project: no prior computing experience is necessary but some knowledge of coding would be useful (e.g., Python and Fortran).

## Further reading or any references referred to in the proposal

- Rice, K., [Origin of Elements and Formation of Solar System, Planets, and Exoplanets](#), *Astrobiology: An Evolutionary Approach*, CRC Press, 19-48, 2014.
- Proxima Centauri b discover paper: doi:10.1038/nature19106
- GPS model description paper: doi:10.5194/gmd-7-3059-2014
- Overview of biosignatures: doi:10.1089/ast.2015.1404.

## Project summary

Development of models of atmospheric dynamics and chemistry to describe the atmosphere of early Earth to understand whether viewing atmospheres of Earth-like exoplanets can provide information about biological life.