Simulating Exoplanet Atmospheres

Prof. Tim Merlis' *research uses computer models to expose the physical mechanisms underlying changes in both past and future climates. While his previous work primarily focused on Earth's atmosphere, he recently was part of a collaboration that worked to simulate exoplanet atmospheres.*

What question were you trying to answer?

Radiative transfer calculations---tracking the emission and absorption of light by the atmosphere and determining how much heating or cooling results---are a critical component of climate models. The codes used to make these calculations are typically developed for Earth's atmosphere, but we wanted to use them understand the climate of Earth-like exoplanets! We also wanted to understand how the ways of doing this important calculation can affect how close a planet can be to its star before its climate is unstable and therefore uninhabitable.

Artist's impression of an Exoplanet with a star peaking over the horizon.

Why did you find this question interesting?

I joined this informal international project with the aim of understanding differences in fully three-dimensional climate simulations. A big focus for my research is atmospheric winds and their impact on precipitation and surface temperature for Earth's climate, so it was really exciting to join a comparison of different climate simulations for exoplanet climates. It turns out there are big differences even before you consider the turbulent atmospheric flow, which led to the research on one-dimensional differences from radiative transfer.

What did you find?

It *does* matter how the radiative transfer calculations are done. There can be big differences. The differences between calculation methods for exoplanets have a much bigger (several fold) effect on climate than all of the carbon dioxide emissions humans have produced over the last century for Earth's climate.

What does doing your research look like?

We performed numerical calculations. Some sit behind a computer ... though the adventurous ones stand behind a computer.

Did anything unexpected happen during this project?

I joined the McGill Space Institute! While I was doing this research, I was pleasantly surprised to learn there was a new Institute being proposed at McGill that would be devoted, in part, to exoplanets.

What role did collaboration play in your research?

This project was 100% collaboration! It is the definition of the sum being greater than the parts: any one calculation on its own would not be too exciting. But by comparing across different methods revealed important differences that meaningful alter the range of planetary orbits that are habitable.

Why this is important

We are still the early stages of using numerical models to simulate the climates of exoplanets (5 years ago when I started doing this, you could count them on one hand). The numerical models are based on those used to simulate Earth's climate, but they are pushed out of the comfort zone where we can compare to Earth observations. There are many comparison projects where identical boundary conditions are used for well controlled sensitivity studies for projections of future changes for Earth's climate. This is one of the first efforts to do so for exoplanet atmospheres.

Yang, J, J. Leconte, E. T. Wolf, **T. Merlis**,et al. (2016), *Differences in Water Vapor Radiative Transfer among 1D Models Can Significantly Affect the Inner Edge of the Habitable Zone*, Astrophys. J. 826, 222..