Research Proposal: Clouds and Weather on Hot Jupiters

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1 Aim

This research aims to generate models of 'Hot Jupiter' exoplanetary atmospheres for a range of host stars, in order to understand how the host star affects the cloud formation and weather on exoplanets. The results of the research will be incorporated into the Centre for Exoplanet Science's ongoing research into atmospheric evolution and will hopefully be used for observations with James Webb Space Telescope in the search for life in the universe.

2 Background

Cloud formation and weather are two of the most important processes that affect the properties of exoplanetary atmospheres. Clouds are the primary mechanism by which heavier elements circulate throughout the atmosphere, and the weather patterns determine how these clouds are distributed throughout the atmosphere. Modelling these processes is required for a comprehensive theoretical understanding of exoplanetary atmospheres and could potentially aid in the search for life on exoplanets.

However, it is not well understood how the host star affects the cloud formation and weather patterns within an exoplanetary atmosphere. This relationship is needed for upcoming observations, since astronomers will need to know which stars to observe to detect exoplanets with certain cloud formation and weather patterns. Therefore, the results of this research could have an impact on the search for exoplanets where cloud formation is a key factor.

Hot Jupiter atmospheres are key to understanding all types of exoplanetary atmospheres. It is expected that half of all the exoplanets detected by the James Webb Space Telescope will be Hot Jupiters because of their large size and short orbital period. Their atmospheres are also the easiest to observe, therefore the models of these planets are the easiest to test with observations. Most of the processes in Hot Jupiter atmospheres will also affect the atmospheres of rocky planets, hence their importance for the study of exoplanetary atmospheres.

3 Impact

The results of this research could have an impact on the search for life in the universe using bio-tracers. Bio-tracers are molecules whose presence in an atmosphere may potentially be used to infer the existence of life on an exoplanet. Currently, it is only possible to observe exoplanetary atmospheres, therefore bio-tracers remain the only viable method for detecting life.

Recent publications from the Centre for Exoplanet Science [1] show that cloud formation and weather will affect the distribution of bio-tracers throughout the atmosphere. Therefore, any model that predicts the observational properties of an atmosphere containing bio-tracers will need to account for these processes. If it is known how the host star affects these processes, then this can be used in follow up research to determine how the host star determines the presence of bio-tracers in exoplanets. It will then be known which stars should be observed to find planets that are likely to contain bio-tracers.

The question this research seeks to answer is related to the main goals of the James Webb Space telescope. One such goal is to investigate the potential for the origins of life in other planetary systems [2]. However, astronomers need to know what stars to observe with the telescope to find planets that are likely to contain bio-tracers, since they are the only way we currently have of detecting life. Cloud formation and weather must therefore be a consideration when selecting stars to observe.

4 Research Plan

The first week will be spent reading any required scientific literature and creating a dataset for the model atmospheres. The models will then be generated and the results documented, noting any initial findings.

Over the next couple of weeks, all information regarding cloud formation and weather patterns will be collected for each model instance. Then, the model instances will be carefully analysed and compared, in order to identify all similarities and differences with regards to the cloud formation and weather patterns. Also, the range of stellar type that produces the largest variance in the results will be identified for use in further simulations.

The next week will be used to run the simulation within the smaller spectral range identified previously. The findings will again be documented and analysed in a similar fashion as for the initial dataset.

A week will then be spent documenting the research and its results. This leaves an additional week to make allowances for any difficulties that may arise, or any unexpected findings that require further runs of the simulation to explore fully.

Given that the project is theoretical, there will be no need to access laboratory or observatory facilities within the university. Any observational data used would be from previous research and made available online. The code required for the simulations would be accessed remotely over the internet, and all software required for the simulations is available commercially.

5 Expected Results

The research will produce a description of the properties of cloud formation and weather that are most sensitive to the host star, and in what way they are sensitive. The description will also specify whether or not there are host star types that induce little or no cloud formation. There will be an explanation as to why these relationships exist, and any unexplained relationships or findings will be identified and recommended for further study.

Even though the research does not concern bio-tracers specifically, they are a significant part of the motivation for the research. Therefore, there will also be a brief discussion of how the cloud formation properties of specific stellar types may influence the likelihood of bio-tracer existence. This will be based on current research, but more work will need to be done to explore this question fully, especially given that the research only deals with Hot Jupiters.

References

1. Woitke P, Herbort O, Helling C, Stüeken E, Dominik M, Barth P, Samra D. Coexistence of CH4, CO2 and H2O in exoplanet atmospheres. Astronomy and Astrophysics. 2020 Oct 17.

2. Gardner JP, Mather JC, Clampin M, Doyon R, Greenhouse MA, Hammel HB, Hutchings JB, Jakobsen P, Lilly SJ, Long KS, Lunine JI. The james webb space telescope. Space Science Reviews. 2006 Apr 1;123(4):485-606.