

Physics & Astronomy PhD Project Proposal

Project Title: Modelling the upper atmospheres of brown dwarfs and exoplanets

Project reference: STFC - Nichols

Groups: Planetary + Astrophysics

Supervision Team:

- Prof. Jonathan Nichols, jd4@le.ac.uk
- Prof. Tim Yeoman, yxo@le.ac.uk
- Dr Sarah Casewell, slc25@le.ac.uk

Three Key Points

- The magnetic field is a fundamental property of a cosmic body, and the recent discovery of powerful aurora-like emissions from very cool stars and brown dwarfs promises a new window into understanding these objects and exoplanets.
- You will model the ionospheres of brown dwarfs and exoplanets to calculate electrical conductance and resulting auroral power
- You will use computer programming to produce the first model of a brown dwarf's ionospheric conductivity, and compare results with JWST data

Project Description

The vast majority of the visible universe exists in the plasma state, and the magnetic fields of cosmic bodies are natural laboratories for studying space plasmas and the bodies themselves. The discovery of auroral-like radio bursts from very cool stars has led to the proposition that extremely powerful magnetospheric processes similar to those which drive auroral current systems at planets in the solar system may be in operation. This, along with upcoming JWST observations of infrared auroras, would provide a new window into understanding the properties and evolution of brown dwarfs and exoplanets, and extend our understanding of space plasma processes outside the solar system. Theoretical models, developed at Leicester (Nichols et al., 2012; Turnpenney et al., 2017), which calculate the auroral power suggest such processes should be detectable on brown dwarfs and some exoplanets. If so, this would enable the characterisation of substellar objects beyond that presently available. However, one fundamental parameter which governs how much power can be dissipated in such systems is the electrical conductivity of the upper atmosphere, which is unknown. Models suggest close-orbiting hot Jupiters could have extremely high ionospheric conductance, but there are as yet no estimations for brown dwarfs, presenting a gaping hole in our understanding of the processes leading to the auroral radio emission from brown dwarfs. It is normally expected that such neutral objects are not strongly ionised, but in previous work we have asserted that, by analogy with Jupiter, an auroral

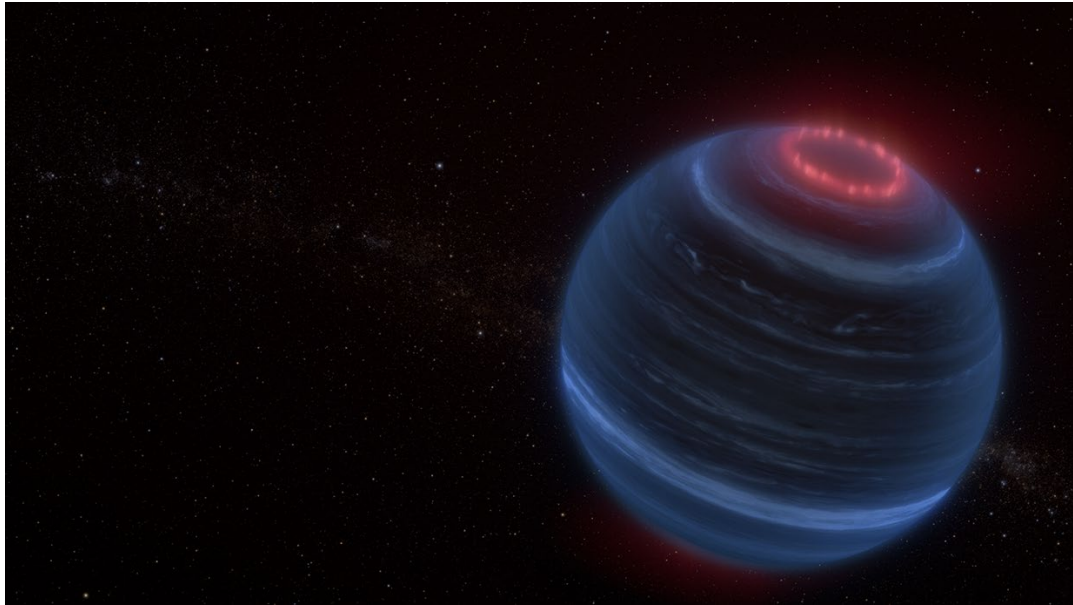
current system at brown dwarfs could self-amplify by generating its own conductivity via the energetic particle beams impacting the atmosphere. In this project we will develop a model of the upper atmosphere of a brown dwarf in order to estimate the conductivities of such objects and determine whether a current system powerful enough to produce auroral radio emissions across interstellar distances is possible. The model outputs will be compared with existing radio observations and JWST observations of infrared auroras on ultracool dwarf LSR 1835+3259, which executed in Cycle 1 and on which the 1st supervisor is a Co-I. We will go on to examine other ionospheric properties and apply the model to relevant configurations of exoplanets. Not only will you work on cutting-edge science, but you will learn new scientific skills such as programming, and writing and presenting work. You will join the Planetary Science research group, an active and vibrant research group which provides a mutually-supportive environment for researchers, but also have links to the Astrophysics research group, which will broaden your exposure to wider aspects of space and astrophysics.

This project is computational in nature, and will initially use the popular Python programming language that is ubiquitous in academia and elsewhere. You will begin with simple 1D analytical models of the upper atmospheres of brown dwarfs considering Chapman Theory, and go on to examine more complex 1D ionospheric models based on those produced for Jupiter (themselves taking heritage from terrestrial studies). As your computer programming skills and experience grow, you may tackle a stretch goal to expand the model to 2D. You will use as input all available information regarding the expected atmospheric parameters and compositions, and external environments of various known radio-loud brown dwarfs. Output conductances will be used to inform pre-existing models of magnetosphere-ionosphere coupling currents to determine whether such current systems powerful enough to be detected across interstellar distances can realistically flow at brown dwarfs. The model outputs will be compared with radio observations and JWST observations

Further Reading:

- Rodríguez-Barrera, M.I., Helling, C., Wood, K., 2018. Environmental effects on the ionisation of brown dwarf atmospheres. *A&A* 618, A107. [Open Access Link](#)
- Helling, C., Casewell, S. Atmospheres of brown dwarfs. *Astron Astrophys Rev* 22, 80 (2014). <https://doi.org/10.1007/s00159-014-0080-0>. [Open Access Link](#)
- Millward, G., Miller, S., Stallard, T., Aylward, A.D., Achilleos, N., 2002. On the Dynamics of the Jovian Ionosphere and Thermosphere: III. The Modelling of Auroral Conductivity. *Icarus* 160, 95–107. <https://doi.org/10.1006/icar.2002.6951>
- Nichols, J.D., Burleigh, M.R., Casewell, S.L., Cowley, S.W.H., Wynn, G.A., Clarke, J.T., West, A.A., 2012. Origin of Electron Cyclotron Maser Induced Radio Emissions at Ultracool Dwarfs: Magnetosphere-Ionosphere Coupling Currents. *Ap J* 760, 59. [Open Access Link](#)
- Turnpenney, S., Nichols, J.D., Wynn, G.A., Casewell, S.L., 2017. Auroral radio emission from ultracool dwarfs: a Jovian model. *Mon R Astron Soc* 470, 4274–4284. [Open Access Link](#)

Images/Graphics:



Credits: NASA, ESA, CSA, and L. Hustak (STScI)

Application advice: Please see web page

<https://le.ac.uk/study/research-degrees/funded-opportunities/stfc>