**University of Leicester Future 100 PhD Scholarship**

**Project Reference: PHYS-Melin**

**Section 1 – *Supervisor Information***

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| **First Supervisor**  | Dr Henrik Melin |
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| **Proposed Second Supervisor** | Dr. Leigh Fletcher |

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| **Additional Supervisor** | Dr. Tom Stallard |

**Section 2 – *Project Information***

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| **Project Title** | Comparative aeronomy of the giant planets in the age of the James Webb Space Telescope |
| **Project Highlights:** | 1. | Reduce and analyse observations of the giant planets from the recently launched James Webb Space Telescope using state-of-the art Python tools.  |
| 2. | By performing spectral analysis of emissions from the molecular ion H3+, determine the relative importance of different heating mechanisms of the upper atmosphere of the giant planets |
| 3. | The candidate will collaborate with international colleagues and with members of the vibrant Planetary Science Group at the University of Leicester, present outcomes at conferences, and publish results in scientific papers, with the guidance and support of the supervisory team.  |
| **Project Overview** |
| The ionosphere is the charged particle component of the upper atmosphere, a critical interface region where energy is transferred between the external space environment and the atmosphere below. At the giant planets (Jupiter, Saturn, Uranus and Neptune) the upper atmosphere is dominated by atomic and molecular hydrogen, yet each ionosphere is remarkably different.The upper atmospheres of all the giant planets are observed to be much hotter than solar input alone can provide, a decades-old mystery dubbed the ‘energy crisis’. The main proposed solutions are the global re-distribution of auroral energy and heating by acoustic/gravity waves generated in the turbulent lower atmosphere. This PhD programme will investigate the relative importance of these processes at Jupiter and Uranus in particular, providing a cohesive view of how the atmospheres and ionospheres of the massive gas giants differ from the smaller ice giants. The James Webb Space Telescope (JWST) is the most powerful infrared space telescope ever constructed and was launched successfully in late 2021. Observations are already in place to observe the giant planets, with the University of Leicester having unique access to some of the first data to be acquired by the space telescope. These observations will provide ground-breaking observations of the atmospheres and the ionospheres of these planets. A dominant ion in the ionosphere of the giant planets is the molecular ion H3+, and via the analysis of its spectrum, obtained via high sensitivity JWST observations, the temperature of the upper atmosphere can be measured, which in turn provides a measure of the local energy balance. The temperature gradients away from potential sources of heating, e.g. the auroral region or storms in the lower atmosphere, can then be used to characterise the efficacy of these processes to heat the upper atmosphere on a global scale. The JWST observations will be put into a longer-term context using ground-based observations using world-class facilities (e.g. Keck, NASA IRTF, VLT).The successful PhD candidate will have some prior experience in coding and the project will predominantly use Python, as well as the High Performance Computer system at the University. The first year of the project will be focused on analysing JWST Jupiter observations, and the candidate will analyse observations of the southern aurora and of the Great Red Spot, two very different energy regimes. With Leicester’s deep involvement with JWST, and the ESA Juice mission to Jupiter, the Planetary Science Group is a vibrant, dynamic and friendly setting for studying the giant planets.  |
| **Methodology**  |
| The JWST observations of Jupiter and Uranus will be reduced and analysed by the PhD candidate using a suite of Python software tools. Python is fast becoming the preferred programming language for data analysis within planetary science, but it is also extensively used within many other sectors. By fitting the H3+ spectrum at near-infrared wavelengths, using a spectral model developed at the University of Leicester, we can determine the temperature and ion density of any particular point on a planet, which reveals the sources of heating in the atmosphere, with temperature gradients providing a view of how this energy is re-distributed globally. The high fidelity snapshots provided by the JWST will be complemented by both archived and future ground-based observations, providing a long baseline of ionospheric variability. The results of this scientific endevour will be presented by the candidate at international conferences and in the scientific literature, and the skill-set required to achive this will be developed with the guidance and support of the supervisory team. Examples of publications in the same topic area, published by our team, can be found below: O’Donoghue, J., Moore, L., Bhakyapaibul, T., Melin, H., Stallard, T. S., Connerney, J. E. P. Tao, C., Global upper-atmospheric heating on Jupiter by the polar aurorae, Nature, 596, 7870, 54-57, 2021, [doi: 10.1038/s41586-021-03706-w](https://www.nature.com/articles/s41586-021-03706-w)Melin, H., The upper atmosphere of Uranus and Neptune, Phil Trans Roy. Soc. A., 378, 2187, 2020, [doi: 10.1098/rsta.2019.0478](https://royalsocietypublishing.org/doi/10.1098/rsta.2019.0478)Melin, H., Fletcher, L. N., Stallard, T. S., Miller, S., Trafton, L. M., Moore, L., O’Donoghue, J., Vervack Jr, R. J., Della Russo, N., Lamy, L., Tao, C., Chowdhury, M. N., The H3+ ionosphere of Uranus: decades-long cooling and local-time morphology, Phil Trans Roy. Soc. A., 377, 2154, 2019, [doi: 10.1098/rsta.2018.0408](https://royalsocietypublishing.org/doi/10.1098/rsta.2018.0408)Johnson, R. E., Melin, H., Stallard, T. S., Tao, C., Nichols, J. D., Chowdhury, M. N., Mapping H3+ Temperatures in Jupiter’s Northern Auroral Ionosphere using VLT-CRIRES, *J. Geophys. Res.*, 2018, [doi: 10.1029/2018JA025511](https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JA025511) Moore, L., O’Donoghue, J., Melin, H**.** , Stallard, T. , Tao, C. , Zieger, B., Clarke, J. , Vogt, M. F. , Bhakyapaibul, T., Opher, M., Toth, G., Connerney, J. E. P., Levin, S., Bolton, S., Variability of Jupiter’s IR H3+ aurorae during Juno approach, *Geophys. Res. Lett.*, 44, 10, 2017, [doi: 10.1002/2017GL073156](https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2017GL073156)  |