**University of Leicester Future 100 PhD Scholarship**

**Project Reference: PHYS-Carter**

**Section 1 – *Supervisor Information***

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| **First Supervisor**  | Dr Jennifer Carter |
| **School/Department** | Physics and Astronomy |
| **Email**  | jac48@le.ac.uk |

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| **Proposed Second Supervisor** | Prof Steve Milan |

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| **Additional Supervisor** | Dr Steven Sembay; XMM-Newton EPIC specialist, PI of SMILE-SXI |

**Section 2 – *Project Information***

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| **Project Title** | Solar wind ion influences at Earth’s magnetosphere: Exploring X-rays with the SMILE mission |
| **Project Highlights:** | 1. | Developing timely and crucial analysis techniques to determine solar wind composition from X-ray observations |
| 2. | Being an integral part of the international SMILE mission team, before and after launch, and during the first stage of science results |
| 3. | Quantify the heavy-ion influences at the Earth’s magnetosphere |
| **Project Overview** |
| Although primarily made of protons and electrons, around 1% of the solar wind is carried by highly-charged ions of various species, the “heavy ions”. Solar wind composition may be used as a marker of broad solar wind type, e.g. highly-charged iron and elevated oxygen states indicate powerful Coronal Mass Ejections (CME). Knowing the solar wind composition is also crucial in understanding the X-ray signal that the upcoming Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) will detect. In 2024, ESA and the Chinese Academy of Sciences will launch SMILE to take the **first ever pictures of the Earth’s highly dynamic magnetosphere**, using its Soft X-ray Imager (SXI). The **University is leading** the SXI instrument and simulator build, using in-house expertise supporting the large European XMM-Newton (XMM) astronomical observatory. SXI spectral analysis has so far been absent from mission preparations. **You will fill this need by developing SXI spectral analysis tools to ensure heavy-ion monitoring continues into the future. You will be an integral part of a cross-disciplinary and inclusive team that straddles both the Planetary Sciences and Astrophysics research groups.** The effect of ion composition on the solar wind-magnetosphere system has not been well constrained. Iron, for example, may leak into and out of the magnetosphere, affecting the delicate mass-balance between the magnetosphere and ionosphere, with implications for space weather modelling. **You will quantify solar wind ions and establish their influence at the magnetosphere.** Currently there is limited solar wind compositional information from spacecraft at low cadences of 2 hours. The anticipated loss of these spacecraft would leave the community without any means of monitoring the solar wind heavy ion conditions at Earth. **You will develop novel remote-sensing techniques to monitor solar wind composition at improved cadences that would be of benefit to the science and space weather community.** Astronomical X-ray observatories such as ESA’s XMM-Newton (XMM) can provide an unusual perspective on the composition of the solar wind (Fig 1). X-ray emission from charge-exchange between solar wind ions and terrestrial exospheric hydrogen produces a series of spectral lines that can be detected in X-rays (~0.25 keV to 2.00 keV). You will develop algorithms to spectrally model these XMM data and identify the dominant ion species. XMM’s large open-access database provides an unprecedented **two solar cycles of X-ray data, allowing solar wind comparisons during solar minimum and maximum.** Fig 1. Example CME spectrumThis timely PhD programme gives you **automatic access to the exciting SMILE mission pre-launch and during science operations**, opening up many future career opportunities. This project is balanced between data analysis, and simulations of existing and new data sets. This work is also of benefit to NASA’s STORM mission, currently in a Phase A study (collaborator: J. A. Carter).For further reading on similar research can be found here:1. Carter, Sembay, & Read, 2010, MNRAS, DOI: <https://doi.org/10.1111/j.1365-2966.2009.15985.x>
2. Carter, Sembay, & Read, 2011, A&A, DOI: <https://doi.org/10.1051/0004-6361/201015817>
3. Branduardi-Raymont et al., 2018, ESA, DOI: <https://doi.org/10.5270/esa.smile.definition_study_report-2018-12>
4. Connor & Carter, 2019, JGR Space Physics, <https://doi.org/10.1029/2018JA026187>
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| **Methodology**  |
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| **Year start** | **Research focus** |
| October 2022 | You will exploit XMM data set under varying solar wind conditions using in-house software. You will compare solar wind type to upstream spacecraft (e.g. ACE, Wind, Cluster), using your own programmes written in Python. You will undertake spectral modelling using the XSpec software package.  |
| October 2023 | You will continue your XMM analysis & investigate the geo-effectiveness of case studies.You will develop spectral models for the SMILE-SXI by programming (IDL, Python). You will make modifications to the SMILE-SXI simulator to include spectral analysis. |
| October 2024 | **This is the launch year for SMILE.** You will continue your SMILE spectral modelling.You will make the first spectral analysis from the first data sets from SMILE. |
| October 2025 | You will continue your spectral analysis of SMILE-SXI data.You will make a request for favourable XMM-SMILE conjunctions via the XMM Science Operations Centre You will write your thesis and several science publications. |

**Your results will be disseminated via high impact journals, various UK and international conferences, and SMILE meetings** |