Dr Luke Barnard

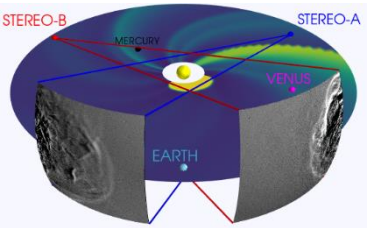
Open source modelling of the Sun's winds

Space scientists Dr Luke Barnard and Professor Mat Owens created a numerical model of the solar wind and published the code Open Source in order to facilitate its use by researchers and space weather forecasters. Within a year of its publication they have established new international collaborations and begun to develop the model as an operational forecast tool for the UK Met Office. Dr Barnard and Professor Owens were **finalists in the University of Reading Open Research Award 2021**.

Space weather is a natural hazard that poses significant risks to our increasingly technologically dependent society, through **impacts to space craft, communications, energy security, and aviation**. The world needs good space weather forecasts. But unlike terrestrial weather forecasting, space weather forecasting is in its infancy. We have gaps in our knowledge, relatively few observations, and we do not yet understand which tools and methods will return the most effective forecasts.

Because there are large uncertainties in observing and modelling space weather, ensemble modelling approaches are particularly useful. In ensemble modelling, a model is run many times with different conditions that reflect the uncertainty in our knowledge of a system. The ensemble of model runs allows us to quantify the uncertainty in a forecast, and interpret it in a probabilistic way. But the main solar wind models are computationally expensive to run, and it is not practical to produce ensembles with enough model runs to be useful in quantifying the uncertainty.

We developed the Heliospheric Upwind Extrapolation with Time dependence (HUXt) model[1] to help solve this problem. In HUXt, we used a reduced physics approach to simplify the model, which makes it much more efficient to run. By focussing on only the key physical mechanisms, we created a solar wind model that runs 1,000 times faster than more complex models, but reproduces their results to within a few per cent. This allows us to efficiently produce much larger ensemble modelling runs, which better represent the uncertainty in our knowledge of the solar wind. These ensembles can now be run by anyone with modest computing resources.



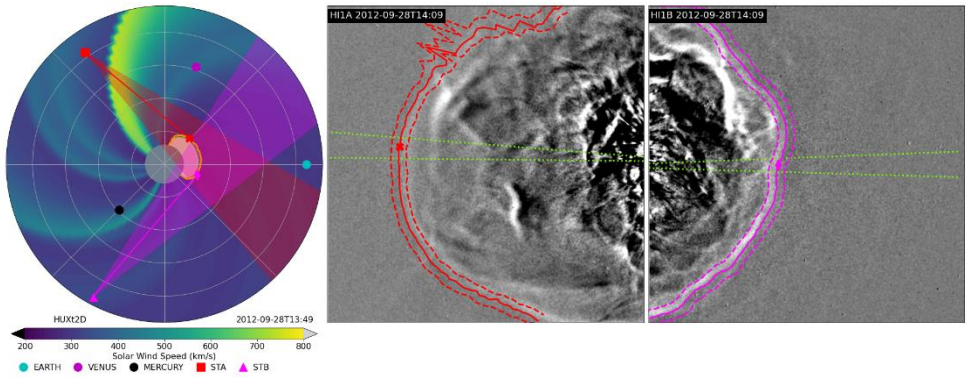
Solar wind speed solution from HUXt compared to white light images of solar wind from NASA STEREO's heliospheric imagers

In developing HUXt, we recognised it could be a useful tool for the research community and space weather forecasting centres. Through our work with **citizen science projects**, and the benefits we have realised in our own work by using other Open Source resources, we understand the importance of Open Research. Therefore, we decided to make HUXt Open Source under the **MIT licence**, and to distribute it via GitHub[2] and Zenodo.[3]

This was a challenging undertaking for us, as providing a software tool to the community demands a level of development above the norm for research software. To help with this, we engaged with other

open research software developers who reviewed our code. Providing software also comes with a commitment to support and maintain it, which is a new experience for our team.

HUXt has already been hugely beneficial to our own research, leading to a promising proof-of-concept study demonstrating how large ensembles can be combined with solar imagery to improve space weather forecasts.[4] This was published in the Gold Open Access *AGU Advances* journal, and submitted through an open peer review process, which was supported by publishing our software for that study.[5]



Comparison between the HUXt solution of a coronal mass ejection with the heliospheric imager observations viewed by NASA's STEREO mission

Alongside the benefits for our own research, distributing the HUXt software has triggered multiple collaborations with colleagues in Europe and the USA. Because we made the code Open Source, the UK Met Office was able to assess the potential of HUXt to be a useful tool for them. As a result, we will further develop HUXt for operational use with the UK Met Office, through a project funded under the UKRI **SWIMMR** programme.

Open at a glance

- Solar wind modelling software source code distributed under Open Source licence
- Turning research software into a usable product takes work, and requires commitment to support and maintain
- Open Source distribution can lead to improvements in software quality and new collaborations

References and further information

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2. Barnard, L. and Owens, M. HUXt. Source code. **https://github.com/University-of-Reading-Space-Science/HUXt**
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