Disentangling the effects of spotty stars from exoplanet atmosphere observations

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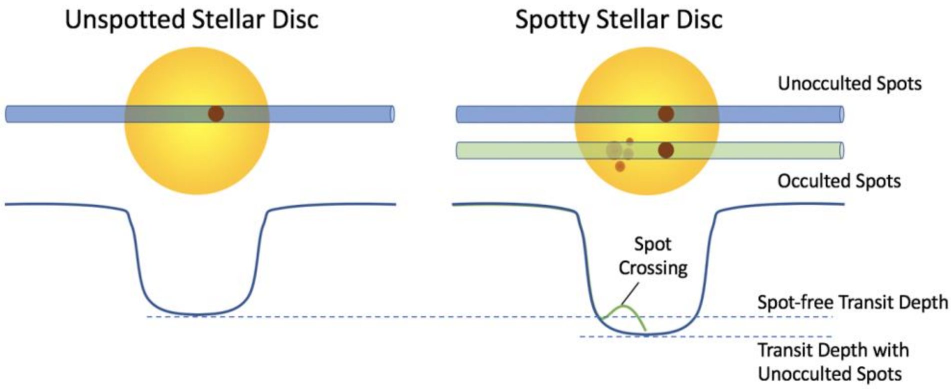

Project highlights:

1. During this project, the student will work to develop simple representations of the effects of starspots and faculae on exoplanet transmission spectra. These will be incorporated into models used to interpret observational data from JWST, to ensure that atmospheric information about the planet is correctly recovered. The student will do this using NEMESIS, a retrieval program written in Python and Fortran that uses a nested sampling wrapper algorithm to sample spectra generated from various atmospheric models and provide the best fitting range of solutions for a given observation. The majority of the work for this project is anticipated to be with the Python part of the code, but some experience of Fortran would be an asset.
2. The simple models for NEMESIS will be tested against synthetic observations created using more complex and realistic models of stellar surfaces, developed by external supervisor Dr Yvonne Unruh. These will then be applied to JWST and Hubble data, to ensure accurate interpretations of atmospheric information, and to provide an insight into characteristics of the stellar surface.
3. The student will have the opportunity to participate in the preparation for the Ariel mission, due to launch in 2029, for which the tools they will develop will be required. The Open University provides a diverse range of internal training opportunities, covering areas from good research practice to media engagement. The student will also be encouraged to attend the annual UK Exoplanet Meeting, and at least one international conference during their studies.

Project description:

With the current operation of JWST, we are entering a new era in the study of exoplanet atmospheres. JWST provides new access to infrared wavelengths and, due to its large primary mirror size, much higher precision than data from the Hubble Space Telescope. This allows us to use the technique of transmission spectroscopy to much greater effect than previously.

When a planet passes in front of its parent star from our viewpoint, some of the starlight passes through the planet's atmosphere. If we measure how much light is transmitted as a function of wavelength, and compare our observations with atmospheric models using 'retrieval' algorithms, we can infer the composition of the planet's atmosphere. Access to the infrared enables us to detect a much greater range of molecules.

The transmission spectroscopy technique contains an implicit assumption that the part of the star the planet crosses during transit is representative of the whole visible disc, but this isn't necessarily true. Stars have starspots (cooler regions) and faculae (hotter regions), which are often not uniformly distributed across the surface. If the region the planet crosses is particularly spotty (or unspotty) relative to the rest of the disc, this can introduce artefacts in the measured planetary spectrum that require correction.

During this project, the student will work to develop simple representations of these effects that can be incorporated into the models used to interpret data from JWST. NEMESIS is a retrieval program written in Python and Fortran that uses a Nested Sampling wrapper algorithm to sample spectra generated from various atmospheric models, and provide the best fitting range of solutions for a given observation. The majority of the work for this project is anticipated to be with the Python part of the code, but some experience of Fortran would be an asset.

The simple models for NEMESIS will be tested against synthetic observations created using more complex and realistic models of stellar surfaces, developed by external supervisor Dr Yvonne Unruh. These will then be applied to JWST and Hubble data, to ensure accurate interpretations of atmospheric information, and to provide an insight into characteristics of the stellar surface.

The Ariel mission, due to launch in 2029, aims to recover population level statistics of exoplanet atmospheres. The tools developed by the student will be vital for correcting for stellar effects on Ariel data, and there will be opportunities for involvement in mission preparation. The Open University provides a diverse range of internal training opportunities, covering areas from good research practice to media engagement. The student will also be encouraged to attend the annual UK Exoplanet Meeting, and at least one international conference during their studies.

References:

1. NEMESIS – Irwin et al. (2008), The NEMESIS planetary atmosphere radiative transfer and retrieval tool, JQSRT 109 1136 https://ui.adsabs.harvard.edu/abs/2008JQSRT.109.1136I/abstract
2. NEMESIS, JWST and starspots – Barstow et al. (2015), Transit Spectroscopy with the James Webb Space Telescope: systematics, starspots and stitching, MNRAS 448 2546 https://ui.adsabs.harvard.edu/abs/2015MNRAS.448.2546B/abstract
3. Effect of starspots on transits – Rackham et al. (2018), The Transit Light Source Effect: False Spectral Features and Incorrect Densities for M-dwarf Transiting Planets, ApJ 853 122 https://ui.adsabs.harvard.edu/abs/2018ApJ...853..122R/abstract