Contamination of Exoplanet Transits

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Introduction

Transit spectroscopy is the most powerful method of exoplanet discovery, contributing to over 75% of confirmed findings. However the presence of stellar variability produced by magnetic activities, such as starspots and faculae (small-scale magnetic flux tubes) introduces noise to exoplanet transits. We focus on the contaminated spectra due to unocculted faculae and their impact on planetary radius determination.

Methods

We employed stellar variability code `actress`, which allows realistic forward modelling of transits, populated with surface faculae. It also takes account of limb darkening - a gradual decrease in intensities from disc centre to its limb.

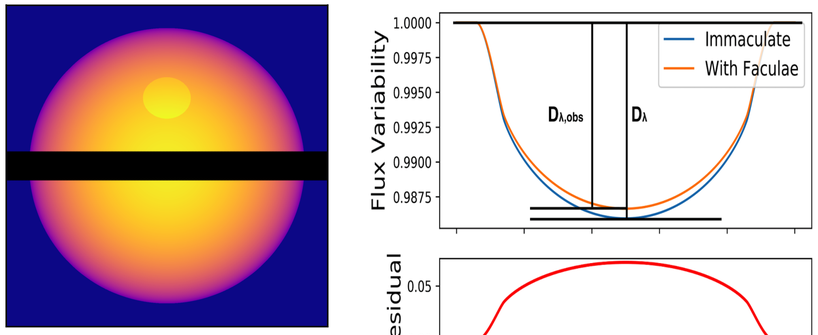

Figure 1: (left) A bright facular feature and planetary transit chord. (right) Transit lightcurve where D_λ is the transit depth. Planet-to-star radius is proportional to the magnitude of transit depth. Hence the contamination induced by faculae has an impact on the estimation of planetary radius.

Contamination Spectra ϵ_λ

Rackham et al. (2019) suggested a correction to account for facular contamination as

$$\left(\frac{R_p}{R_*}\right)^2 = D_\lambda = \frac{D_{\lambda,obs}}{\epsilon_{\lambda,fac}} \qquad \text{where} \qquad \epsilon_{\lambda,fac} = \frac{1}{1 - f_{fac}\left(1 - \frac{F_{\lambda,fac}}{F_{\lambda,phot}}\right)} \tag{1}$$

where $F_{\lambda,phot}$ and $F_{\lambda,fac}$ are the spectra of immaculate photosphere and facular photosphere respectively, and f_{fac} is the filling factor of the features.

References

[1] Benjamin V Rackham, Dániel Apai, and Mark S Giampapa. The transit light source effect. ii. the impact of stellar heterogeneity on transmission spectra of planets orbiting broadly sun-like stars. *The Astronomical Journal*, 157(3):96, 2019.

[2] PFL Maxted and S Gill. qpower2: A fast and accurate algorithm for the computation of exoplanet transit light curves with the power-2 limb-darkening law. *Astronomy & Astrophysics*, 622:A33, 2019.

Lightcurve Reconstruction

Motivation: `actress` is unable to retrieve parameters from lightcurves. `qpower2` (Maxted et al. 2019) is a fast and accurate algorithm to study how unocculted faculae affect the radius determination of exoplanets.

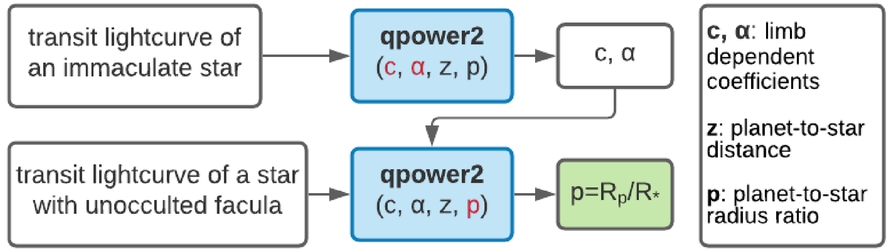

Figure 2: Lightcurve reconstruction process in calculating ratio of planet-to-star radius.

Results

Contamination Spectra

Discrepancies between simulated and actual lightcurves are well-described by Rackham's equation. Contamination spectra can subsequently be applied to transmission spectra to take account of stellar variability.

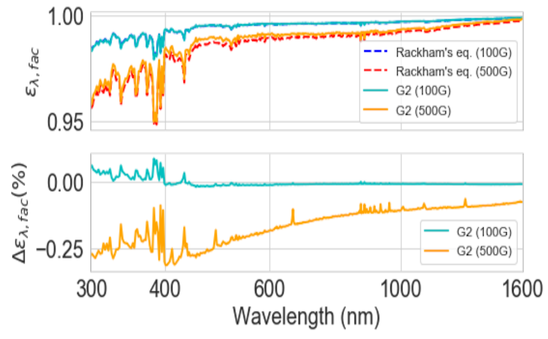

Figure 3: Contamination spectra from Eq. 1 of G2-type star at different magnetic field strengths with $f_{fac} \approx 2.61\%$.

qpower2

Recovered radii are robust to errors in the limb darkening (see crosses), and that radii are underestimated if one does not correct for faculae.

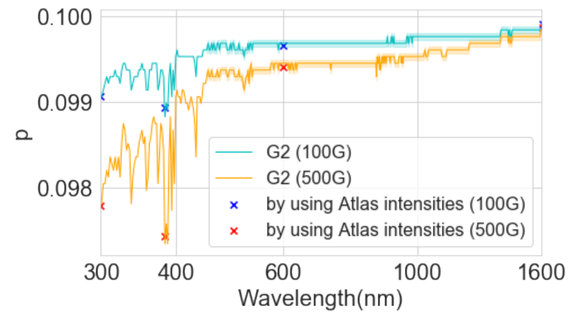

Figure 4: Plot of p against wavelength for a G2 star of $\langle B_z \rangle$ = 100G and 500G, with $f_{fac} \approx 20\%$ as Figure 1. The cross represents the hot-star spectrum with the equivalent effective temperature without magnetic activities.

Conclusion

Rackham's contamination spectrum is good approximation if faculae are evenly distributed across the stellar surface. However it fails to correct radius determination for large facular filling factor.