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Searching for Young Exoplanets with *TESS*

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Introduction

While a diverse zoo of over 4000 verified exoplanets has now been discovered, there are still many unanswered questions regarding their formation and early evolution. Obtaining a sample of **young (<1Gyr) exoplanets** with well-defined ages will help to fill this gap in our knowledge. Here recent work in the search for young exoplanets in stellar associations is presented, using data from the *Transiting Exoplanet Survey Satellite* (*TESS* - Ricker et al., 2015). This includes the development of a new light-curve detrending pipeline optimised for young stars and an exploration of sensitivity to injected model planets. The work summarised here is discussed in detail in **Battley, Pollacco & Armstrong (2020).**

I – The opportunities and challenges of young stars

Stellar associations are a key place to find planets around stars of well-defined ages. These associations are diffuse groups of stars with similar composition, positions and ages which share a common space motion across the sky. However, young stars pose significant challenges to detecting exoplanets due to their increased activity and much faster rotation rates compared to the general stellar population. Indeed stellar activity can result in signals with **periodic variability greater in amplitude but similar in duration to planet signals**, both in photometric (Fig 1.) and spectroscopic data. This effectively masks planetary signals from traditional detrending pathways, motivating the design of new detrending methods to find planets around these stars.

In order to maximise the number of young stars analysed, the *TESS* 30min cadence Full Frame Images (FFIs) were chosen as the primary data source, applied to stars from Gagné et al.'s (2018a; 2018b) BANYAN survey of stellar associations. Through comparison to the 2min light-curves the Difference Image Analysis (DIA) pipeline of Oelkers & Stassun (2018) was chosen as the main method of extracting light-curves from the FFIs.

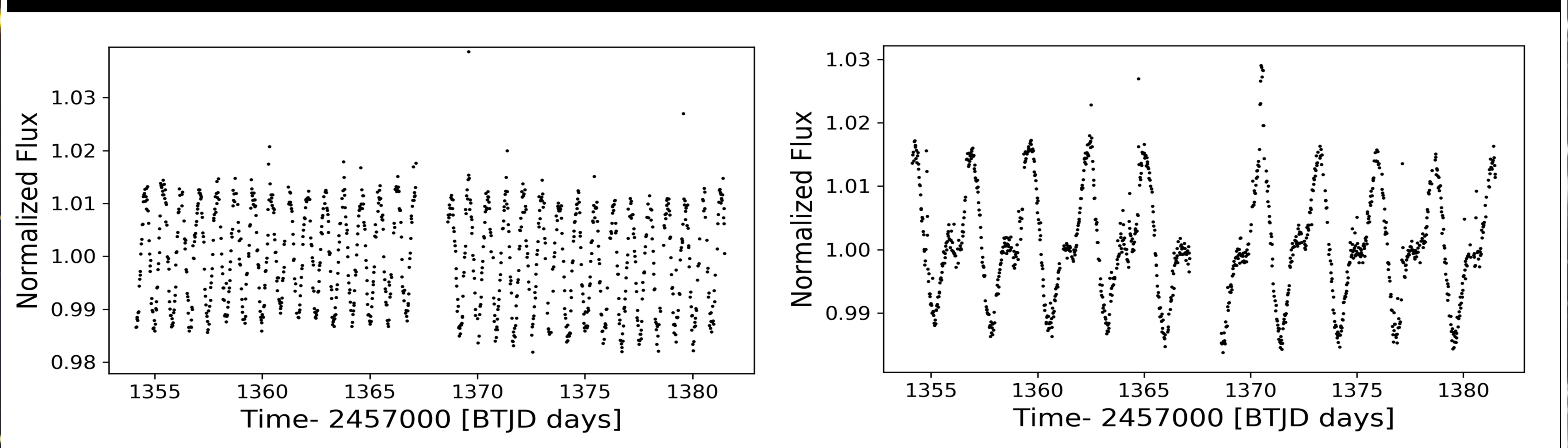

Fig 1. Examples of the young star light curves after extraction from the FFIs via the DIA challenging stellar activity, variability and rotation observed in the pathway. Left: J0015-2946; Right: J0024-2522, both from *TESS* Sector 2

II - Detrending methods and recovery of DS Tuc A b

Traditional transit-search detrending methods such as that performed on the TESS 2min light curves struggle to cope with the large-amplitude and short-timescale variability often observed in young stars. In response to this challenge a new detrending pipeline based on an adapted **Locally Weighted Scatterplot Smoothing** (LOWESS) method has been developed, which includes activity interpolation over any suspected transits, as demonstrated in Fig 2. It was also found that in many cases with sharp oscillations, recovery of injected transit signals was improved by cutting off the peaks and troughs of the oscillation, which otherwise may be seen as spurious signals in the analyses of the main periods present. While challenges such as very fast rotation and unpredictable activity remain, this pipeline has already shown promise in the **recovery of the 45Myr exoplanet DS Tuc A b** (Fig 3.).

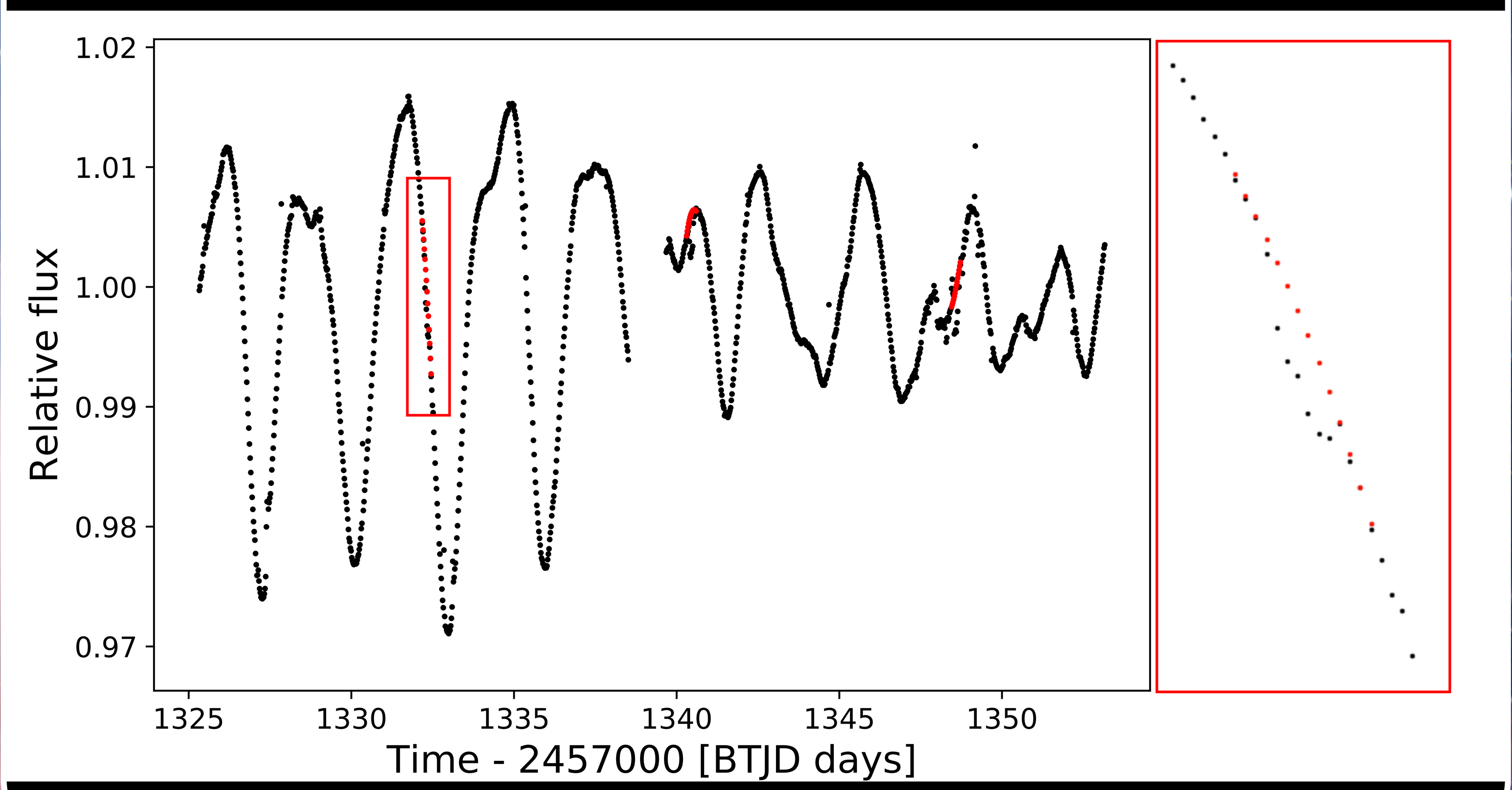

Fig 2. The activity interpolation option within the pipeline in use.

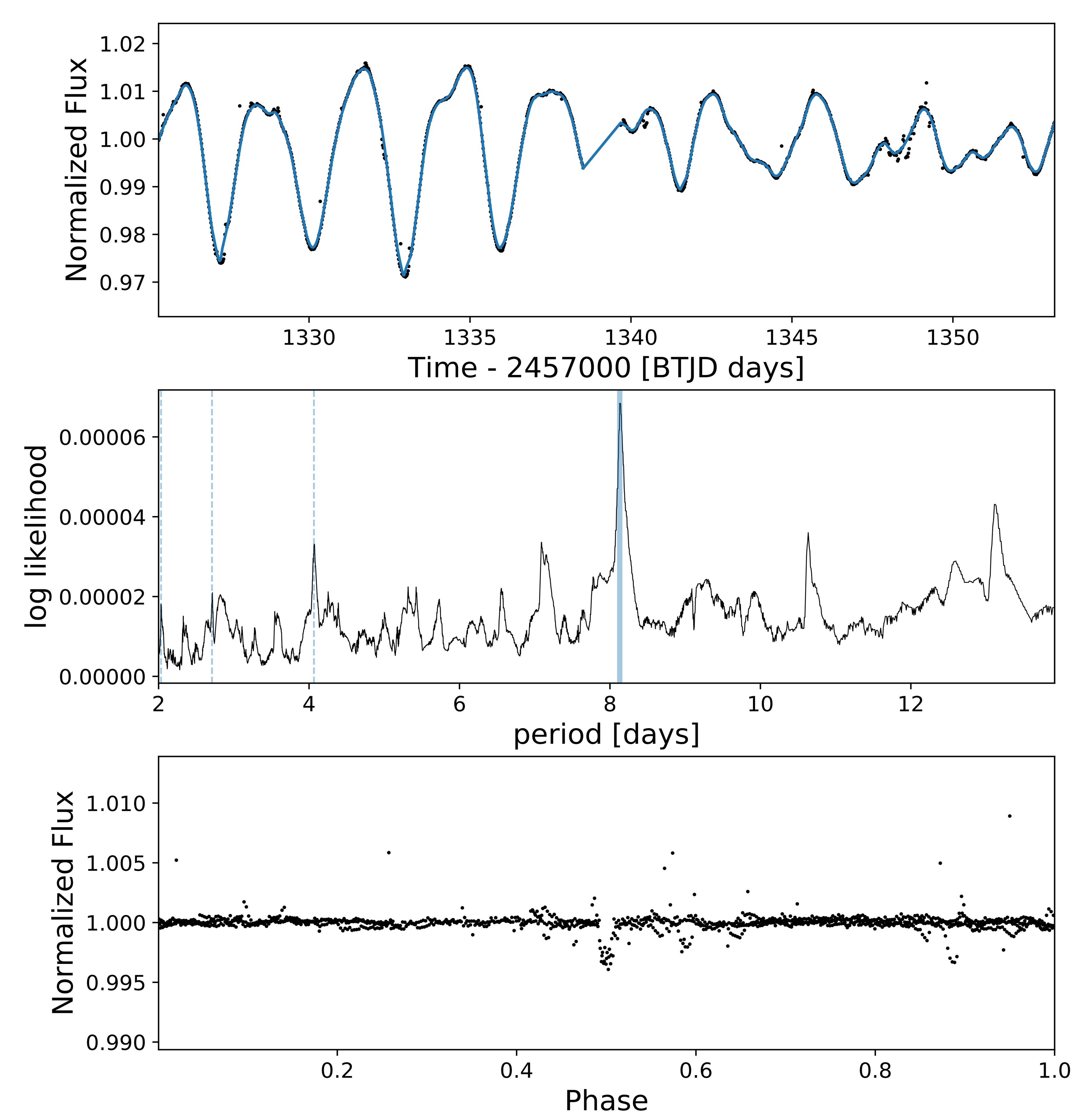

Fig 3. Detrending and recovery of the known young exoplanet DS Tuc A b

III – Overall Sensitivity Analysis Results

In order to test the sensitivity of this detrending technique to finding exoplanets around such active stars, a full injection and recovery analysis was undertaken, inserting model transits into each original light-curve. The overall results of this analysis are shown in Fig. 4. As expected the overall recovery rate for planets dropped off with decreasing planetary radius, yet curiously the relationship between recovery rate and planetary period was more complex, with **recovery peaking around periods of 2-6 days** for stars in this sample. Interestingly the recovery rate and depth did not appear to be significantly correlated with activity period aside from a steep drop-off for stars with periods of one day or less. Meanwhile **the peak-cutting technique was found to be most effective for light-curves with rotation periods of 2-8 days**, however did not result in detrimental recovery depth performance between 2-15 days, unless light-curves were essentially flat. These results are very promising for future searches using this pipeline.

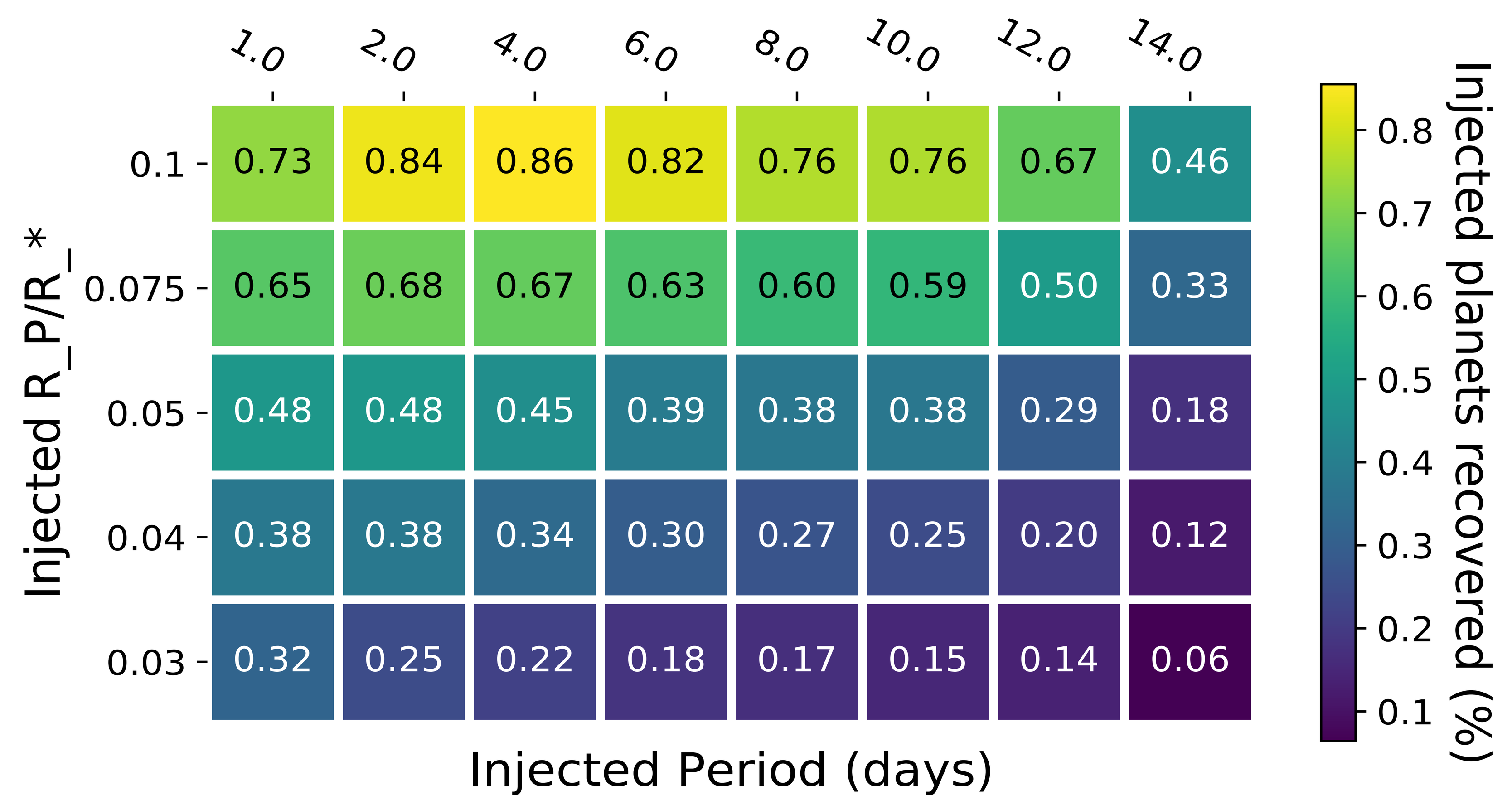

Fig 4. Sensitivity results showing percentage recovery of injected planets

Future Prospects and Challenges

The pipeline presented here has already shown significant promise in the search for exoplanets around active young stars. However **a number of key challenges still remain** before large numbers of young exoplanets can be found. Most important are solving the problem of very short period activity (<1 day) and increasing the number of known young stars. In addition, given the large variety of stellar activity types viewed in young stars, improved radial velocity techniques are required to differentiate between stellar and planetary RV signals and thus confirm any new planets. Nonetheless, it is clear that the search for young exoplanets can now begin in earnest.

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