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Detecting giant planets orbiting low-mass stars to understand how planets form

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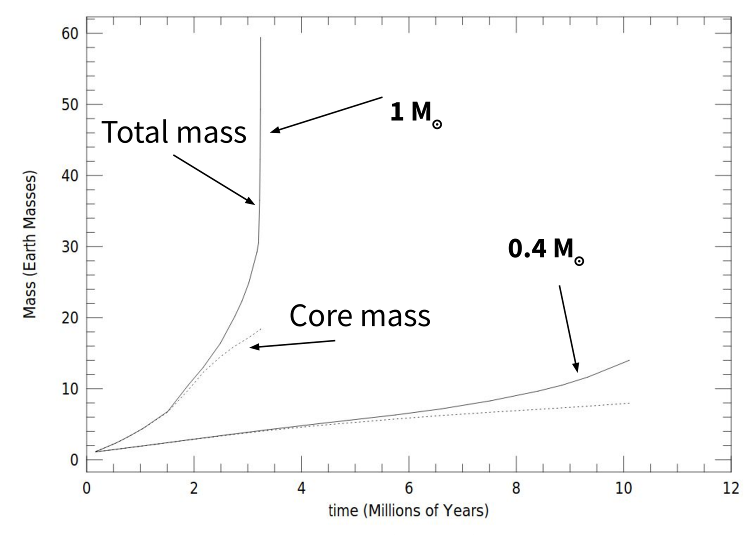
Recent discoveries of giant planets orbiting low-mass stars (eg. HATS-71b; NGTS-1b) challenged currently held theories for planet formation. Specifically, these systems should not be able to form through core-accretion.

We set out to exploit the TESS-FFIs to conduct a systematic search for such systems. Our ultimate goal is to quantify the occurrence rates of these planetary systems.

Check out the flowchart to find out how we are doing this, and how many objects (roughly) we have at each stage!

If you have any questions please get in touch!



Laughlin et al. (2004) [1]

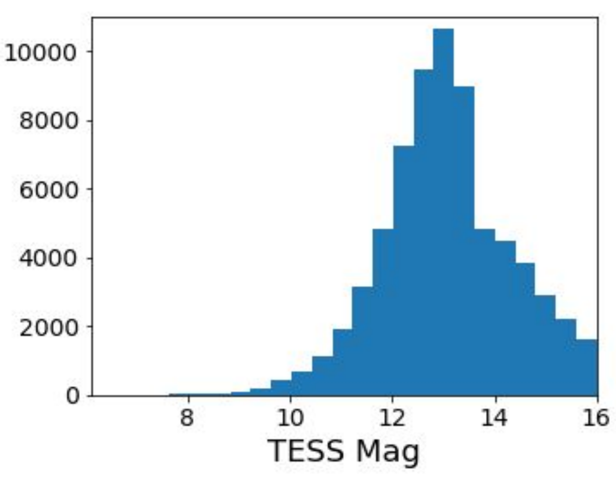
Target Sample: 68945 low mass stars

Select stars from TICv8 with:

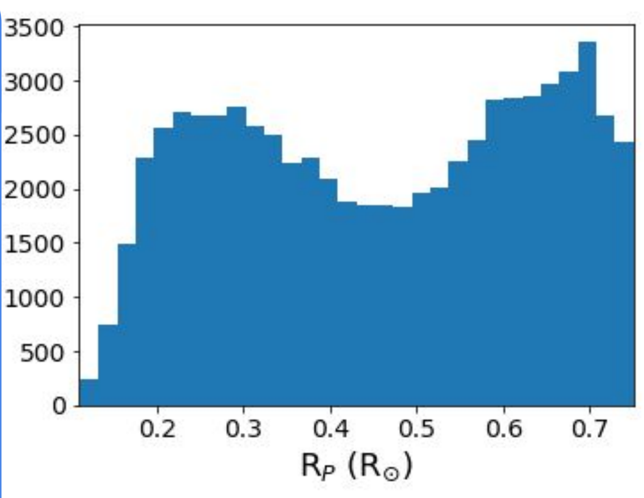
$T \leq 16$ mag $R_* \leq 0.75\ R_\odot$ $T_{eff} \leq 4500$ K

Identify which have a TESS-SPOC 30 min cadence FFI light curve [2]

We start with the available data in the North (sectors 14-26), and plan to include targets in the South when the data is available



Brightness distribution of our initial Northern stellar sample



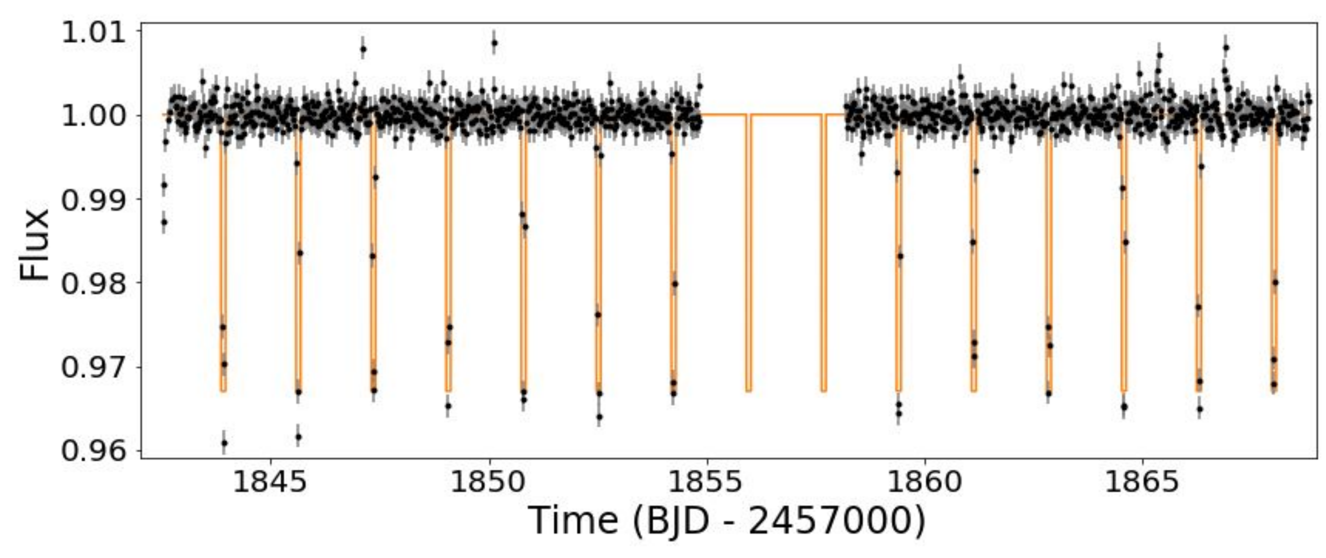
Radius distribution of our initial Northern stellar sample

Candidate Detection ~ 2500 BLS Hits

Candidates are identified using the Box Least Squares (BLS) algorithm

The high precision of TESS and the large transit depths of these systems make these very significant events

BLS does a wonderful job at finding them



An example BLS detection for one of our candidates

Candidate Vetting ~ 1000 Vetted Objects

BLS also does a good job at finding false positives

Eg. Eclipsing binaries and Variable Stars

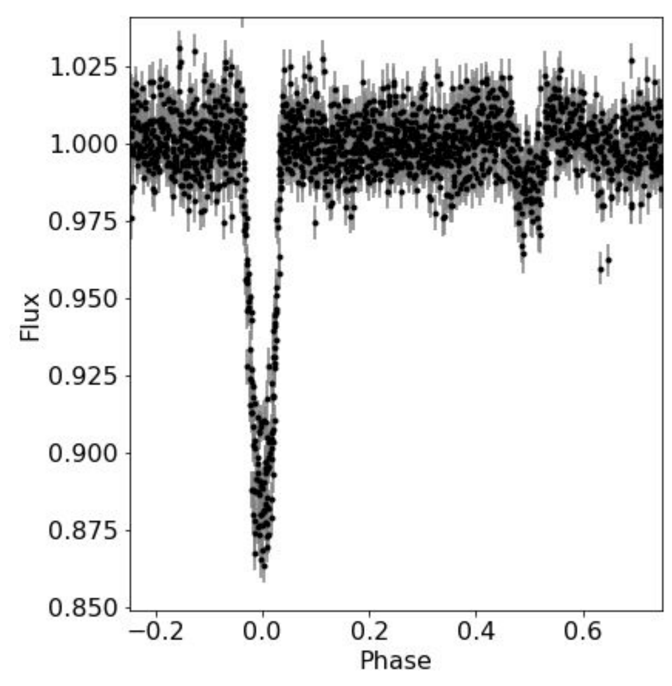
We use standard vetting checks to identify these, such as checking for secondary eclipses and odd-even depth differences

These checks are performed in a **quantitative manner**

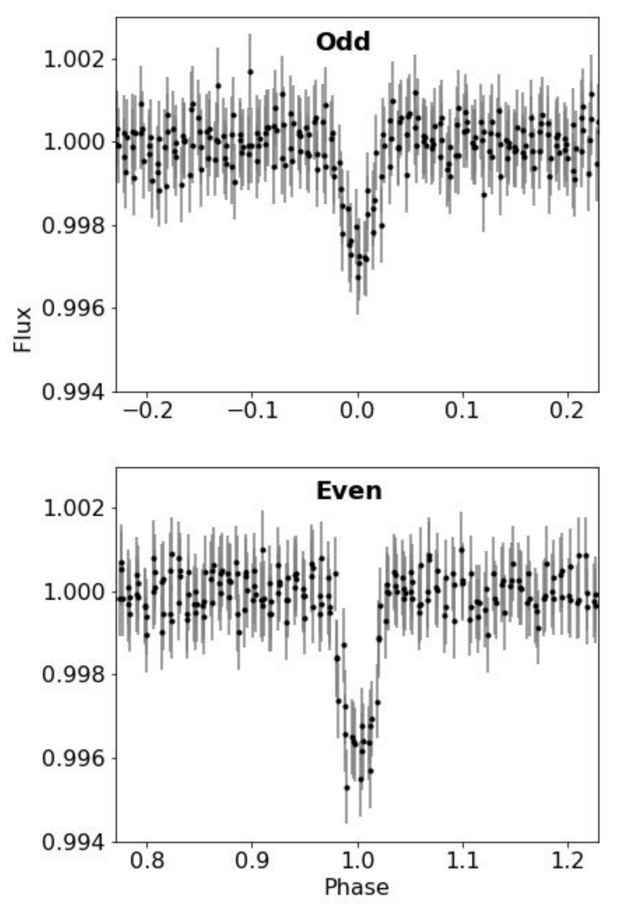
Each star can be treated exactly the same, so we are statistically robust across the full sample

This is important for calculating **occurrence rates**

Eclipsing binary identified from a secondary eclipse



Eclipsing binary identified from an odd-even depth difference

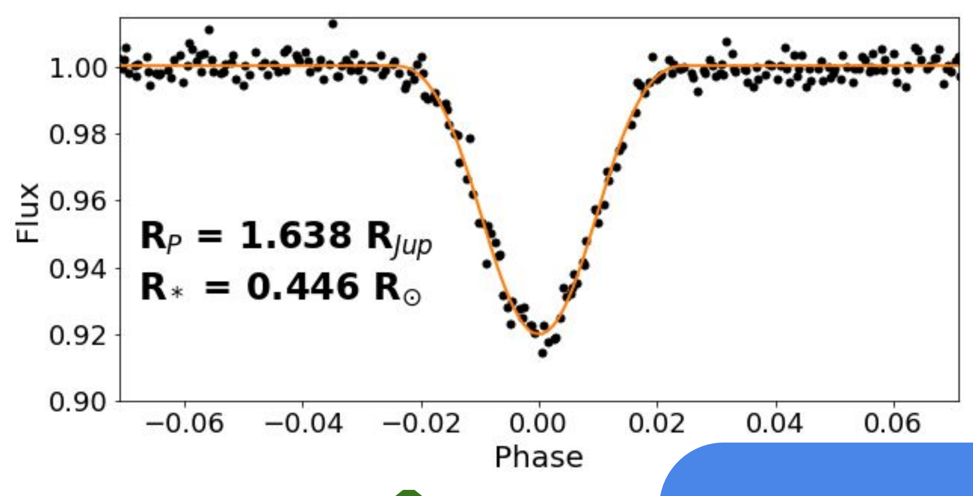


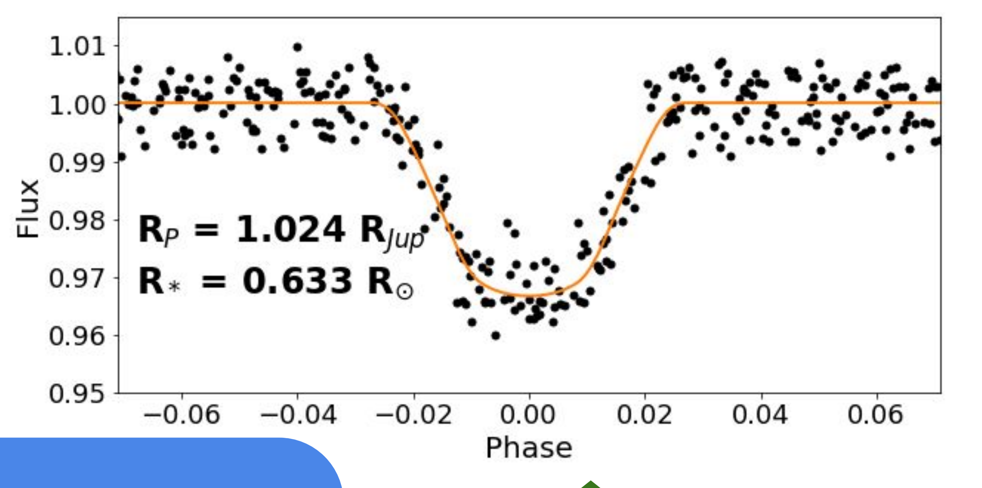
Transit Modelling ~ 35 Giant Planet Candidates

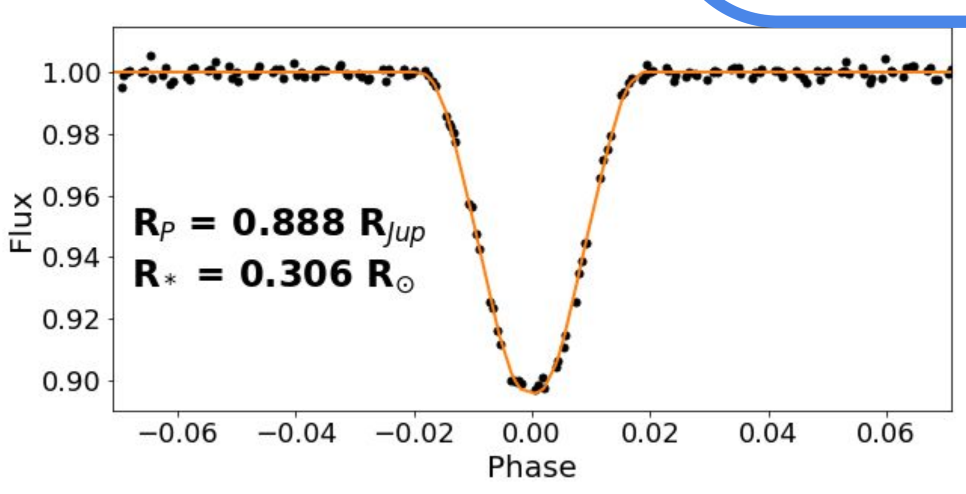
We model the transits of our vetted objects to

1. Determine **companion radii**
2. Assess **transit shapes** and **durations**

We can now identify the objects which are likely to be **transiting giant planets**







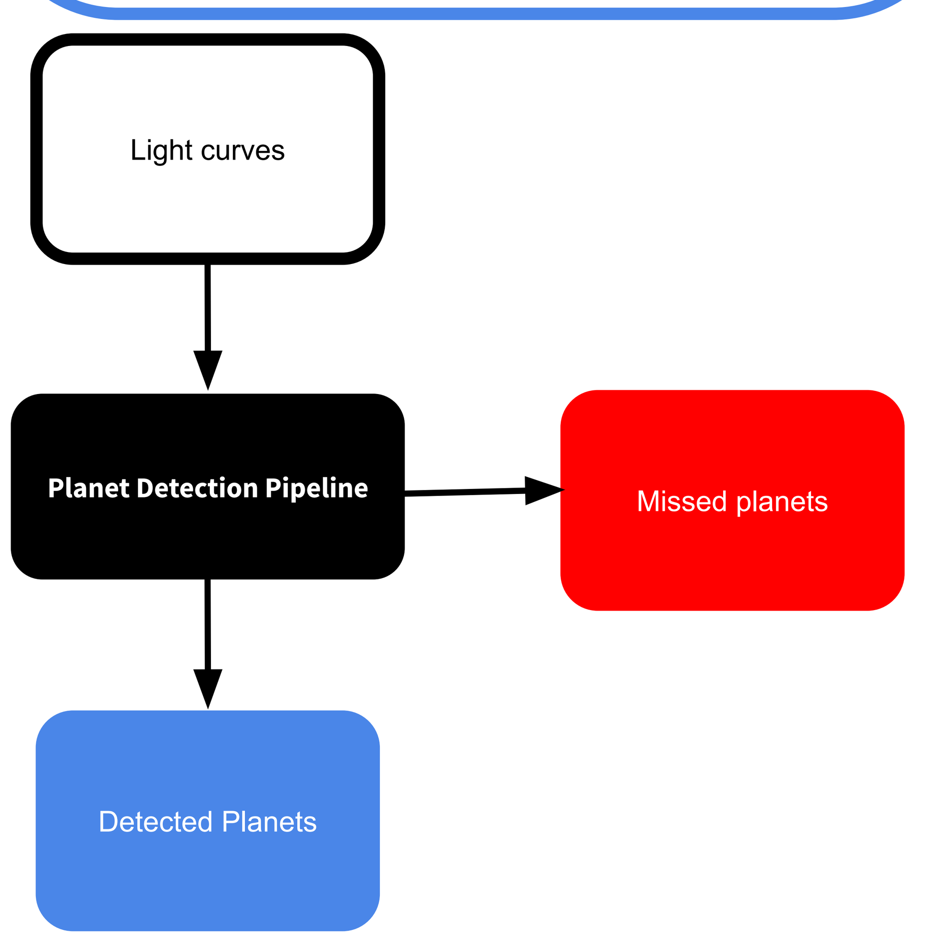
Injection - Recovery Tests

Our pipeline will not detect every planet

To calculate **occurrence rates** we need to quantify our **detection efficiency**

We will inject simulated planet transits into TESS light curves

We can then determine what percentage of these simulated planets are detected, and what percentage are missed, by the pipeline

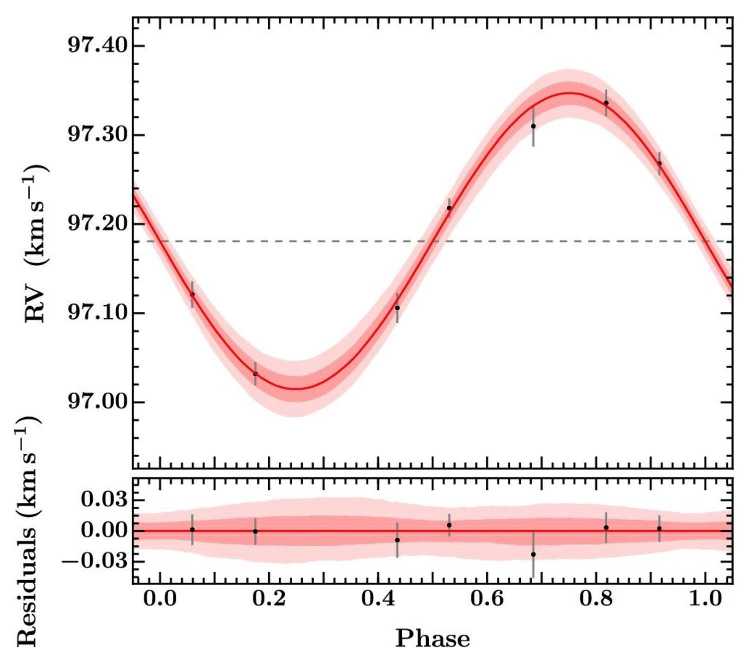


BONUS: Mass Measurement

We will measure the masses of the top planet candidates found by this search

This is a bonus outcome of the project

The radial-velocity signals are large for these systems. See the RV curve for NGTS-1b from Bayliss et al. (2018) [3] below



Summary and Future Work

Giant planets orbiting low-mass stars are predicted to be rare
We use data from the TESS FFIs to perform a **statistically robust planet search** for these systems

We will perform **injection-recovery tests** to allow us to **quantify occurrence rates** for these systems
These results will be important for **understanding how planets form**

We will also measure the masses of the best giant planet candidates

Thanks for reading. Please get in touch if you have any questions!

References:
[1] Laughlin, G; Bodenheimer, P; Adams, F. C. 2004, ApJ, 612, 1, L73-L76
[2] Caldwell, D. A. et al., 2020, RNAAS, 4, 11, 201
[3] Bayliss, D et al., 2018, MNRAS, 475, 4, 4467-4475

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