IDENTIFYING TRANSITING NEPTUNES AND SUB-NEPTUNES IN THE NGTS SURVEY THROUGH CROSS-CORRELATING WITH TESS TOIS

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Through cross-correlating TESS [1] Objects of Interest with NGTS [2] survey fields, we noticed that some TOIs are not always independently discovered by NGTS. Using the TESS ephemeris and period to phase-fold the NGTS data, we can recover previously overlooked transiting planet candidates in the NGTS survey. Owing to the shallower transit depths, around half of these previously missed candidates are Neptune and sub-Neptune sized, some in multi-planet systems. Through combining TESS and NGTS data, the number of transits and the baseline of observations can be greatly extended, particularly where NGTS data precedes the TESS data, in some cases by several years. This leads to improved ephemerides, and potentially improves estimates of planetary radii and other parameters. It can also be beneficial for multi-planet systems, aiding the search for additional planets or assessing the data for Transit Timing Variations.

Candidate Selection

To extract candidates that have not been independently flagged but are likely have a clear transit detection in NGTS survey data when we refit the data, we restrict by the conditions below:

7147 TOIs (15th May 2024) → 362 appear in NGTS Survey Fields → 208 still have PC flag on ExoFOP; 154 are eg. KP, FP, EB etc. → 176 are >1mmag; 32 are shallower than the NGTS noise limit → 117 have a BLS detection in NGTS; 59 have no NGTS transit detection → 58 previously unclassified by NGTS; 59 already identified as NGTS Objects of Interest

Scan the QR code for an animation of this process!

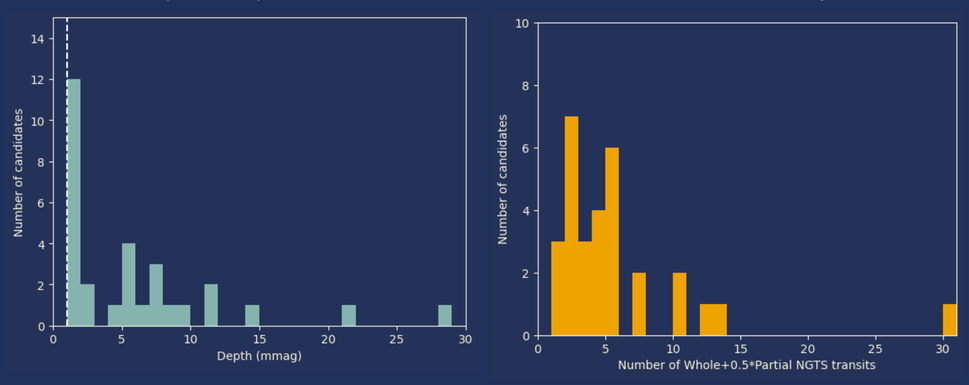
After refitting these 58:

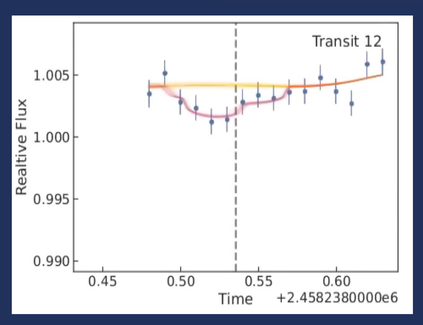
- 27 successful transit retrievals in NGTS Survey Data (11 of which are Neptunes/Sub-Neptune sized!)
- Reject 15 as non-planetary, insufficient NGTS transit coverage or otherwise non-detection
- More are still in progress...

Why were they missed?

Several factors make transit identification more difficult for these candidates:

- Shallow-ish; 1-2mmag is detectable but difficult for a NGTS single camera
- Low S/N or minimal in transit data
- Multiplanet systems or other stellar noise confuses the BLS algorithm





Overlapping transits in NGTS data for TOI-1027b and d!

This can cause ORION (BLS algorithm used on NGTS) to pull out the wrong period, so an eyeballer wouldn't see anything of interest. If the correct period is retrieved, they may not be flagged since shallow transits don't always look real.

We can aid our candidate flagging procedure either through using the candidates in this project to train a neural network [3] or through Citizen Science Projects such as Planet Hunters NGTS [4].

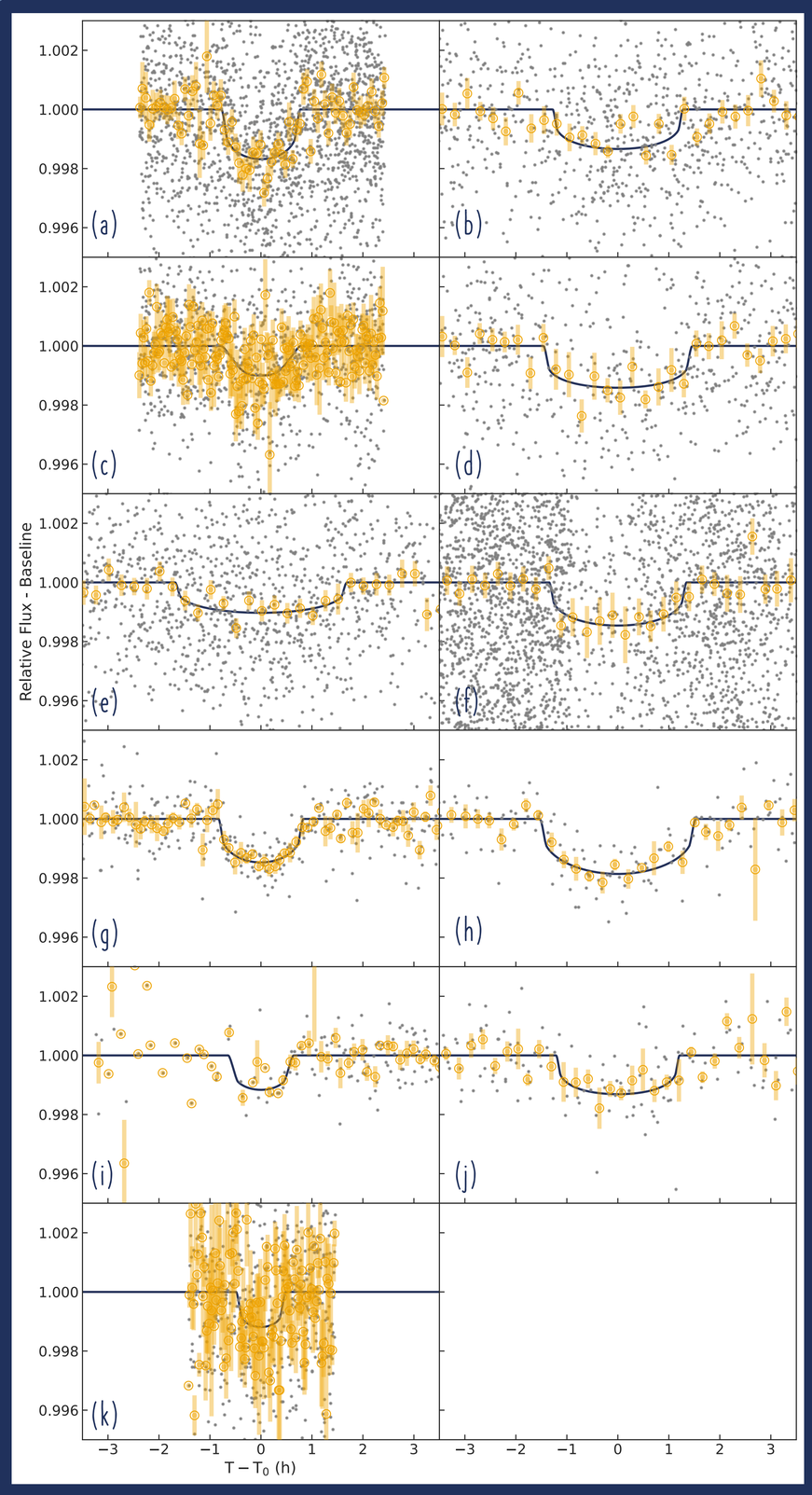


Fig.1 NGTS phasefolded lightcurves from joint fits with TESS data for each object: (a) TOI-168b, (b) TOI-475b, (c) TOI-612b, (d) TOI-761b, (e) TOI-875b, (f) TOI-929b, (g) TOI-1027b, (h) TOI-1027c, (i) TOI-1027d, (j) TOI-4662b, (k) TOI-6100b. Grey dots are binned to 2 minutes, orange are binned to 15 minutes.

Conclusions

- The key outcome is that we can find the shallow transits of Sub-Neptune and Neptune sized planet candidates in NGTS survey data, even a few in the Neptunian desert, we just needed some assistance from TESS to overcome ground-based telescope challenges. This could help to add to the two NGTS planets published from survey data of a similar size: NGTS-4b [5] and NGTS-14Ab [6].
- If you have a TOI, NGTS may have high quality data for your paper! Either through survey mode like this project or simultaneous multicamera observation requests, get in touch ☺

Fig.2 The blue dots are confirmed planets from the NASA Exoplanet Archive [7], limited to those with uncertainties σ_p < 6 hours and σ_r < 20%. The blue colour bar and contours represents the number of planets per element of the meshgrid used (500x500), which has been uniformly spaced in dimensions $\log_{10}(P)$ and $\log_{10}(R_p)$, between 0.2 < P < 200 days and 0.05 < R_p < 3 R_J. The orange circles represent successful candidates included in this project, with the teal filled circles being the Neptunes from Fig. 1. The blue line is Mazeh's Neptunian Desert [8].

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