Validation of TESS candidates orbiting Solar-type stars.

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Giacomo Mantovan (Università di Padova), Marco Montalto (Università di Padova), Giampaolo Piotto (Università di Padova)

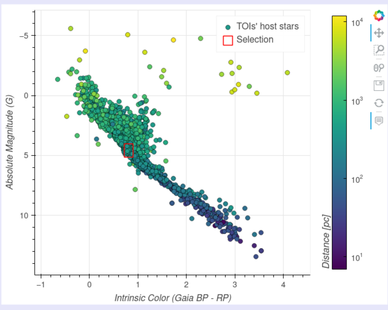
Giacomo Mantovan
giacomo.mantovan@phd.unipd.it

ORCID

Summary

- We selected all the TOIs orbiting Solar-type stars, for which there are not yet available time-series or precision radial velocities observations. We found 375 TOIs and performed their probabilistic validation analysis using the VESPA code
- We statistically validated 61 TESS candidates orbiting Solar-type stars
- We corrected their radius for stellar dilution: 9 of them could be of stellar nature
- We analyzed their stellar neighbourhood to find possible contaminating stars: 11 of them do not have possible contaminants, while the others need further investigation starting from On-Off photometry to confirm the source of the transit signal

How did we select our sample?



Intrinsic color-magnitude diagram

To select the candidates orbiting Solar-type stars, we built an intrinsic color-magnitude diagram in the *Gaia* band, correcting the photometry for distance modulus, extinction and reddening. We calculated the former using the parameters from the Bailer-Jones catalog (Bailer-Jones et al. 2018), while we used the Stilism software (Capitanio et al. 2017) to evaluate the extinction. We obtained the V-band extinction for all the stars and then converted it into the *Gaia* photometric bands with specific conversion factors.

Stars sample

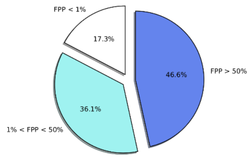
From the color-magnitude diagram, it is possible to extrapolate all the stars belonging to a certain spectral class. We could do this using the Mamajek's table (Pecaut & Mamajek 2013), which provides average color and magnitudes parameters for each spectral class and therefore allows a selection based on them. We selected stars from F9V to G8V spectral classes, took into consideration only Planet Candidates (PC) not under investigation by the TESS team and excluded each TOI for which time-series or Precision Radial Velocity (PRV) observations were already available. In total, after discarding single-transit candidates, 375 TOIs survive within our selection.

Results

False Positive Probability

Statistically validated candidates

On-Off Photometry



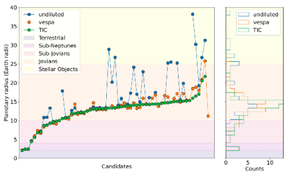
False Positive Probability

We performed the VESPA (Morton 2012,Morton et al. 2016) analysis for 375 TOIs orbiting Solar-type stars and obtained reliable results for 352 of them. In this pie chart, we show the distribution of their False Positive Probability (FPP).

False Positive Probability

Statistically validated candidates

On-Off Photometry



Statistically validated candidates

To claim a statistical validation for a transiting candidate exoplanet we considered the FPP < 1% threshold. We found 61 candidates orbiting Solar-type stars that satisfy this limit.

We then subdivided the entire sample in five arbitrary planet-size bins, to determine which kind of exoplanets we found. In this figure we show the distribution of their planetary radii. Each point with the same x coordinate corresponds to a validated candidate, while its color changes depending on the source from which the radius value comes from. In blue, our custom-estimated radius, which is the one corrected for stellar dilution.

It is worth pointing out the much larger radius value we have obtained for some candidates because the planetary nature itself can become questionable when the boundary between a stellar and a sub-stellar body is reached.

False Positive Probability

Statistically validated candidates

On-Off Photometry

On-Off Photometry

To understand the real nature of a TESS candidate, it is necessary to analyze accurately its stellar neighbourhood to find possible contaminating stars. We can apply the seeing-limited On-Off photometry (Deeg et al. 2009), which consists in the observation of short time windows during the predicted On and Off-transit phases. Thanks to the much higher angular resolution of a ground-based imager, we can confirm that the detected signal is due to a genuine candidate exoplanet orbiting a given target star.

We can exclude a blended eclipsing binary by comparing its observed brightness variation during the two transit phases with the expected variation necessary to reproduce the detected transit signal. However, sometimes we do not need to take a photometric observation because none of the contaminating stars is able to generate a flux in the aperture which corresponds at least to the observed flux variation. In this particular situation, we confirm the target star as the source of the signal and move on to radial velocity observations, otherwise, we require ground-based photometric observations.

Conclusion

Here we presented our ongoing follow-up program of TESS candidates orbiting Solar-type stars without any kind of time-series or precision radial velocity observations available. Our probabilistic validation analysis allows to identify which are the most promising candidates and the evaluation of their stellar neighbourhood determines which is the next follow-up observation needed to confirm the exoplanet candidate. The final goal of the entire procedure is to avoid losing observational time at expensive facilities and optimize follow-up resources. In particular, we statistically validated 61 TESS candidates orbiting Solar-type stars. Eleven of them have been confirmed to orbit their host star and can be prepared for the radial velocity observations, while the others need photometric observations.

References

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