Expanding our horizon: probing the architecture of planetary systems with HARPS and TESS

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ABSTRACT

In order to understand the formation and evolution of small terrestrial planets not only their internal structure but also the architecture of their host system must be known.

Systems harboring long-period cold gas and icy giants (a > 1 au) tend to host close-in small planets (a < 0.3 au, $R_p < 4 R_\oplus$) (Masuda et al. 2020). How does the presence of outer planets influence the formation and evolution of their inner smaller siblings? Unfortunately, our knowledge is still incomplete. Currently, the sample size for these systems is small and the relevant parameters are unknown. To truly understand the physics governing the formation and evolution of small planets we need to know the orbital architecture of their planetary systems.

Here we present results from an ongoing radial velocity (RV) follow-up program conducted with the High Accuracy Radial velocity Planet Searcher (HARPS) spectrograph, mounted at the ESO 3.6m telescope of La Silla Observatory, and its twin for the Northern Hemisphere, the HARPS-N spectrograph, installed at the Telescopio Nazionale Galileo. Our program aims at measuring the mass of small transiting planets discovered by the TESS space telescope. The 4-year baseline of our project is allowing us to search for long-period outer planets, "expanding the horizon" and probing the architecture of planetary systems with inner small transiting planets.

Combining TESS times series photometry with HARPS and HARPS-N high-precision radial velocities, we confirmed the planetary nature of the transit signals and derived masses, radii, and orbital parameters of the planets. Performing a frequency analysis of the RV measurements we also unveiled the presence of additional signals, which are associated to outer orbiting companions.

TESS Target 1

In the first year of observations, TESS discovered a sub-Neptune planet orbiting a F9 V star every 16 days. Our HARPS follow-up led to the discovery of an additional planet, a gas giant at about 300 days.

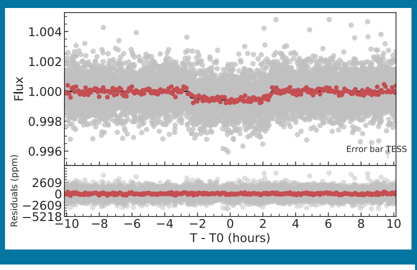

Fig.1: Phase-folded TESS transit photometry and best fitting model for the 16-day planet.

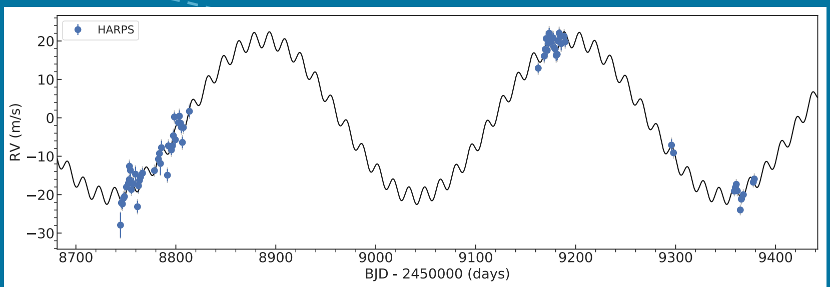

Fig.2: Radial velocity time series and best fitting model.

TESS Target 2

A sub-Neptune planet was found to transit every 30 days this G5 V star. Our intensive HARPS follow-up allowed us to measure the mass of the transiting planet and detect 2 additional low-mass planets at 5 and 14 days, along with a long-period Doppler signal likely associated with stellar magnetic activity.

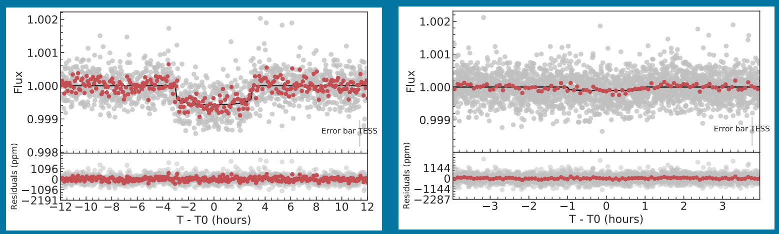

Fig.3: *Left:* Phase-folded TESS light curve for the planet at 30 days. *Right:* Phase-folded light curve for the inner planet at 5 days.

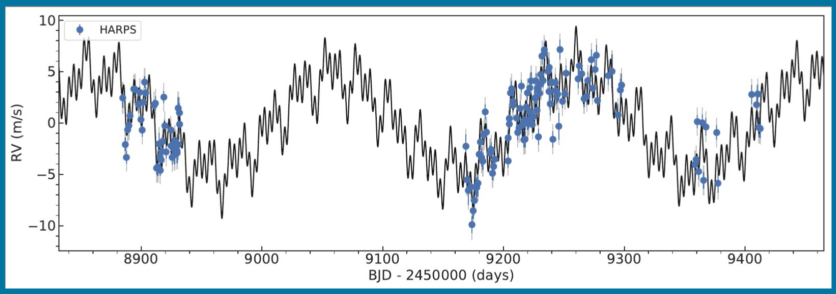

Fig.4: HARPS RV measurements and best fitting model.

TESS Target 3

An ultra-short period (USP, P < 1 day) rocky planet orbiting a bright M-dwarf was observed by TESS in the first and third years of its mission. The HARPS RVs unveiled the presence of an additional signal at about 12 days, associated with an orbiting low-mass planet, along with a long-period signal due to stellar rotation.

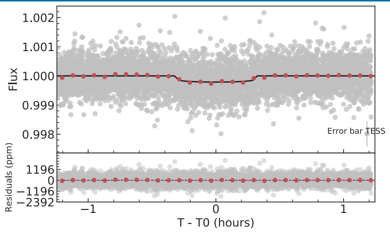

Fig.5: Phase-folded TESS transit light curve of the USP planet with the best fitting model.

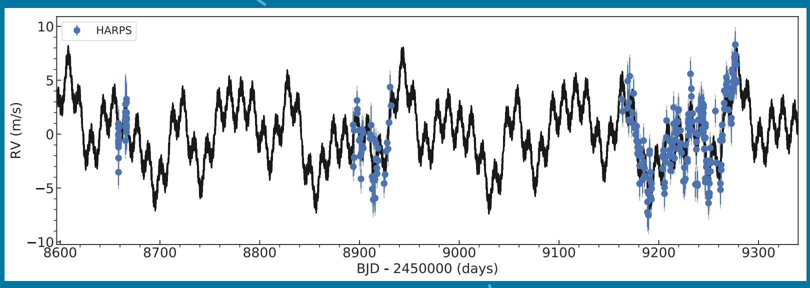

Fig.6: HARPS RVs and best fitting model.

TESS Target 4

This is a G8 V TESS star known to host a transiting hot Neptune with an orbital period of ~3 days. The HARPS-N follow-up unveils the presence of an outer Saturn-mass planet on a 400-d orbit and provided the mass of the transiting planet.

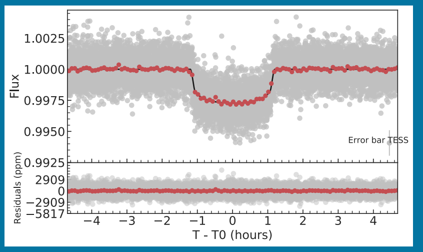

Fig.7: Transit of the hot Neptune as observed by TESS.

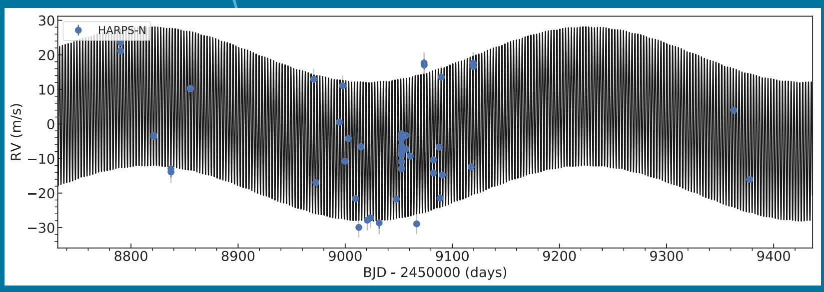

Fig.8: HARPS-N RV measurements and best fitting model.

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