Transiting giant planets around low-mass stars

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Jupiter-mass planets and brown dwarfs are remarkably rare around late K (and early M) dwarfs. Planetary population synthesis models predict a very low occurrence rate of giant planets and even suggest it should decrease to zero for the stellar mass range 0.7-0.3 $M_{\odot}$ (Burn et al. 2021). However, albeit at a seemingly much lower rate than around hotter stars, these companions do exist. There are currently 8 well-characterized (mass precision <25% and radius precision <8%) giant planets orbiting late K stars (K5 to K9) and 10 orbiting M stars. From TESS photometry, Bryant et al. (2023) deduced an occurrence rate of 0.194 ± 0.072 % for the mass range 0.088 - 0.71 $M_{\odot}$. The existence of these rare companions contradicts the currently accepted core-accretion planet formation theory. Characterising giants and brown dwarfs provides more insight into the poorly explored population of rare low mass star companions. A statistically significant sample will allow to constrain late K- and M dwarf giant planet formation and evolution.

K dwarfs

CORALIE - Swiss 1.2m Leonard Euler telescope

Motivated by the relatively few confirmed massive TESS Objects of Interest (TOIs) around late K dwarfs, the CORALIE echelle spectrograph has an ongoing program for TESS follow-up observations of giant planets and brown dwarfs around mid/late K stars. The main focus lies with late K dwarfs, but the sample also includes younger stars and mid-K dwarfs. Aiming to bridge the gap between heavier stars and the very low mass star regime, and to see where the drop of occurrence is exactly located.

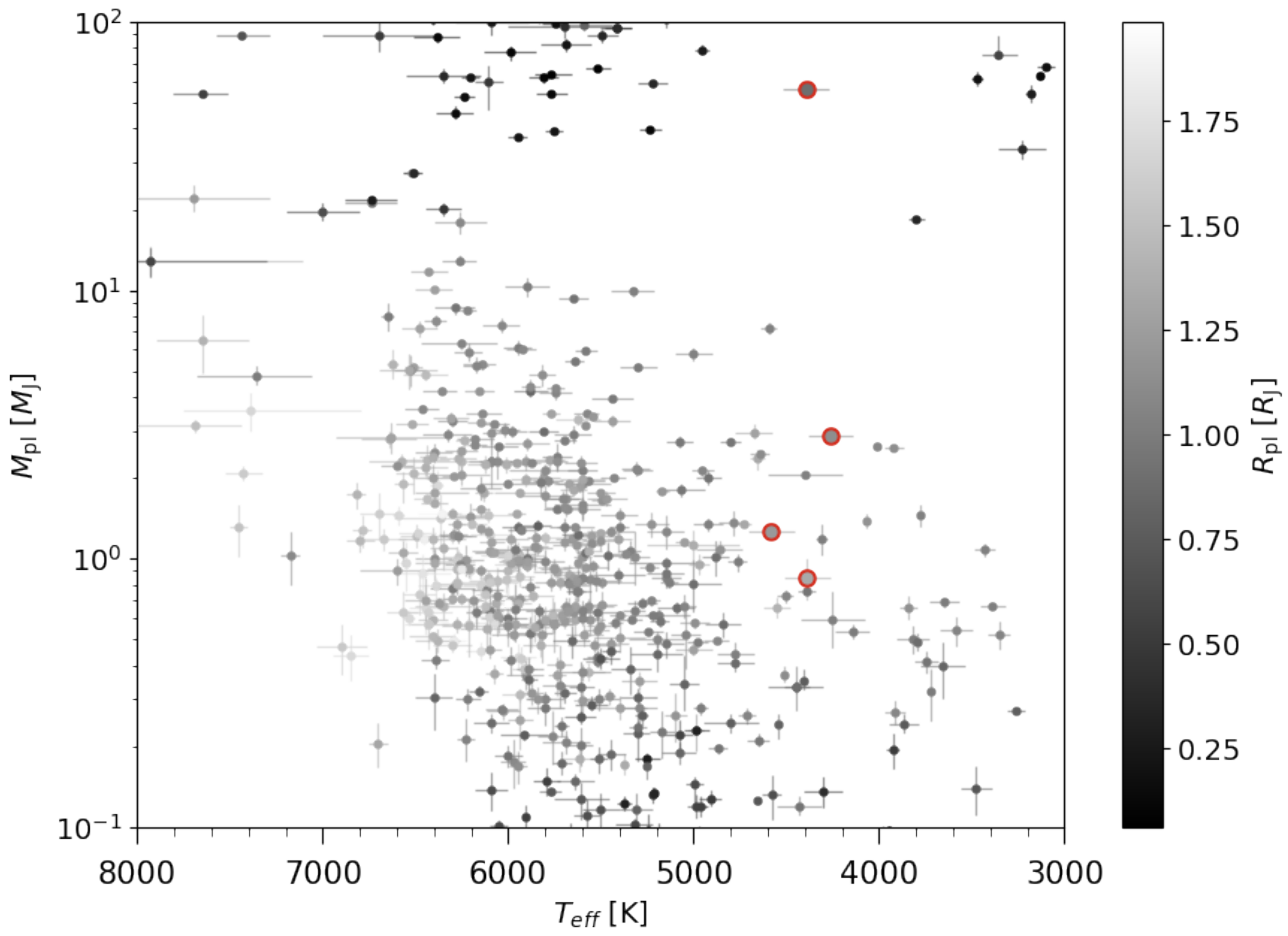
The TOIs are selected on the planetary radius (7.5 - 16 $R_{\odot}$), effective temperature (K4 - K9), and observability in the Southern hemisphere.

The ongoing CORALIE follow-up program has observed 11 targets to date. Among these, 1 is an SB2, 4 have orbital solutions (paper in prep), and 6 are too faint for CORALIE to model an orbital solution. However, these faint targets show no obvious signs of SB1, Brown Dwarfs or massive giant planets, as the RV variations are small and there are no chromatic RV differences.

As the program also includes brown dwarfs, we are probing the transition point between giant planets and low mass stars. With one of our discoveries being at the very edge of this transition point.

For more information see soon to be submitted paper!

Mass versus stellar effective temperature of the up to date discovered exoplanets (PlanetS catalog) and brown dwarfs (13-150 MJup transiting companions as of June 2021, Grieves et al. 2021). Red encircled are the companions found by the ongoing program at CORALIE.

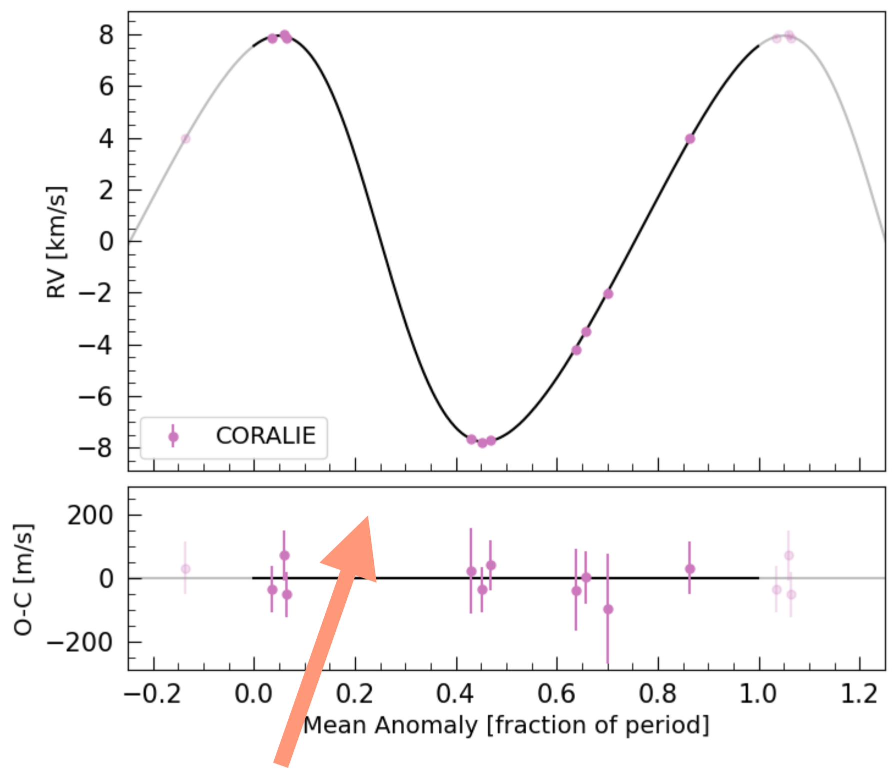


M dwarfs

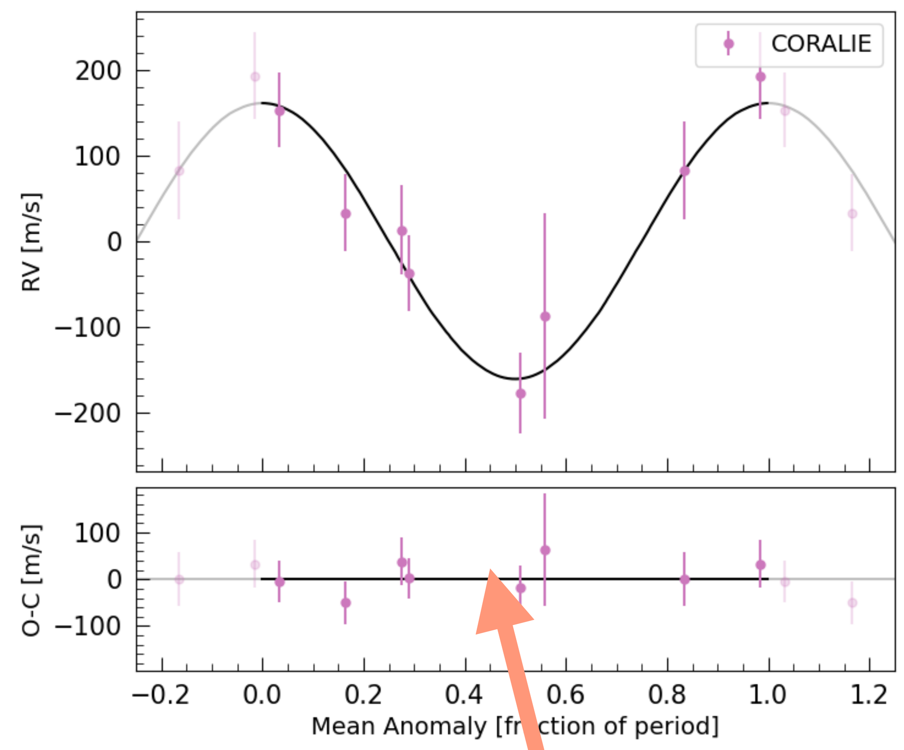
NIRPS - 3.6m ESO telescope

Recently, the Near Infra-Red Planet Searcher (NIRPS) has joined the High Accuracy Radial velocity Planet Searcher (HARPS) at the 3.6-meter telescope in La Silla, Chile. NIRPS is a fibre-fed, adaptive optics-assisted, high-resolution (R ~ 85,000) spectrograph operating in the near-infrared (nIR) range of 950 - 1800 nm. With HARPS working in the optical range, together these instruments cover a wide spectral range, enhancing our ability to detect and study exoplanets.

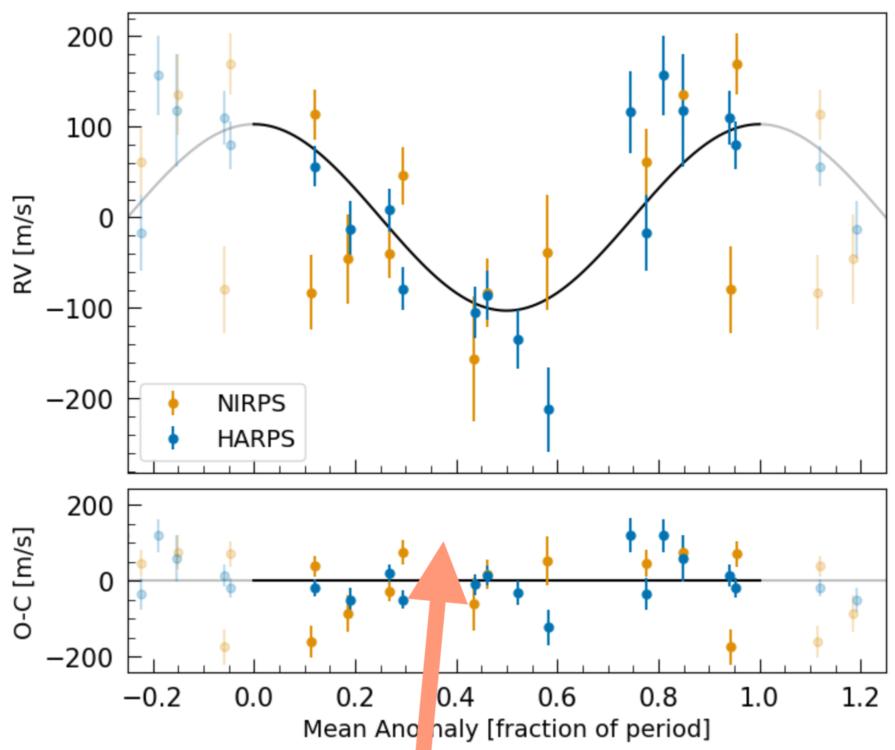
While the CORALIE program specifically targets K dwarfs, NIRPS is designed to be highly sensitive to M dwarfs, covering spectral types later than M0. Observing in the nIR introduces complexities, such as more dominant telluric lines and atmospheric emission lines, which can interfere with the faint signals we aim to detect. To address these challenges, we use telluric corrections, and the data reduction software, adapted from ESPRESSO pipeline, has recently been updated (DRS-3.2.0) to reduce the impact of emission lines. While the observations remain very sensitive to weather conditions, these mitigation techniques have significantly increased the detection capabilities of NIRPS at the faint end.



A brown dwarf companion at the transition point from planet to star
M = 56 M_J R = 0.89 R_J
P = 4.9 days



A very young star (1-20 Myr) with a giant companion
M = 0.9 M_J R = 1.34 R_J
P = 2.3 days



A giant companion orbiting a low-mass M1 dwarf
M = 0.5 M_J R = 1.14 R_J
P = 2.9 days

Though rare they do exist!

Massive companions around low-mass stars exist, albeit at a significantly lower rate than around hotter stars. Transiting- and radial velocity surveys have significantly contributed to these rare companion discoveries. As low-mass stars have radii and masses that are significantly smaller than that of our Sun, more massive and thus larger companions are generally easier to discover and characterize through transits than around Sun-like stars. The ongoing surveys on NIRPS and CORALIE will help distinguish the turning point between giant exoplanets and low mass stars. As well as provide more information for their formation theories. With NIRPS we are now moving towards the nIR, enabling a more precise characterisation of exoplanets around M dwarfs.

Laughlin, G., P. Bodenheimer, & F. C. Adams (2004) ApJL, 612, L73; Bryant, E. M., D. Bayliss, & V. Van Eylen (2023), MNRAS, 521, 3663; Boss, A. P. (2006), ApJ, 643, 501; Burn, R., et al. (2021), A&A, 656, A72; Wildi, F., et al. (2022), SPIE, 12184, 121841H; Grieves, N., et al. (2021), yCat, 365, J/A+A/652/A127