

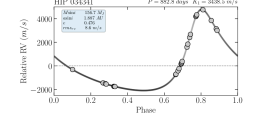
For over two decades RECONS group have been studying stars in the solar neighborhood for two reasons, the possibility of the next habitable world to be within our reach and for the statistical significance of surveying comprehensively a volume-complete sample of stars. We are undergoing **three large scale surveys on ~5000 K dwarfs within 50 pc from the Sun, to find stellar/sub-stellar/planetary companions** with three different techniques: Wide separation companions from precise Gaia astrometry, arcsec-milliarcsec companions with speckle imaging, and unresolved close companions with the radial velocity technique (RV). In this work, we present the progress of our **RV survey on 472 K dwarfs**, which correspond to all the equatorial (DEC +30° to -30°) K dwarfs found up to 33 pc with Hipparcos. Here we outline two subsets: **172 K dwarfs already covered extensively by HARPS and HIRES**, and **300 K dwarfs for which we get RV time-series with a one-year baseline per star using the CHIRON high-resolution spectrograph for 3 years until now, with precisions of ~7-15 m/s** it has proven capabilities to down to detect giant-planet mass companions. In combination with the observations done by other precise RV instruments, up to date **we have covered 90% of our sample**. With these results we aim to overcome the limitations due to selection bias on previous planet searches, and subsequently start to unveil the occurrence and nature of the giant planet population around K dwarf stars from a well-defined volume-limited sample.

The Radial Velocity Survey

- 300 K dwarfs are monitored with multiple observations using CHIRON high resolution spectrograph
- The observing strategy is to complete at least 9 observations separated by few days, a month and a year
- **273 K dwarfs (91%) are fully covered to date**, and 27 (9%) need their one-year apart observations
- Follow-up observations are added when we detect changes on the RV of the star and solve for an orbit
- We have developed a custom pipeline to efficiently extract RVs from thousands of CHIRON spectra

Known Stellar/Sub-stellar Companions

- The main complement to our sample is the SB9 catalog of spectroscopic binary orbits¹, which provides reliable and published orbital solutions for a great number of multiple systems.



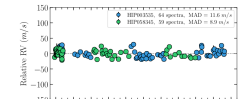
- We also observed known binary systems from SB9 to validate our companion detection methods by achieving nearly identical orbital solutions.

Known Planets

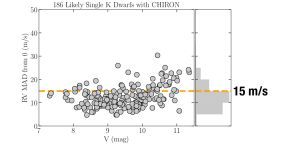
- Of the 472 K dwarfs, **172 were already covered intensively by HARPS and HIRES**, two of the most sensitive RV planet searchers spectrographs, with precisions below 5 m/s.
- 19 planets previously discovered were obtained from the NASA Exoplanet Database².

Single

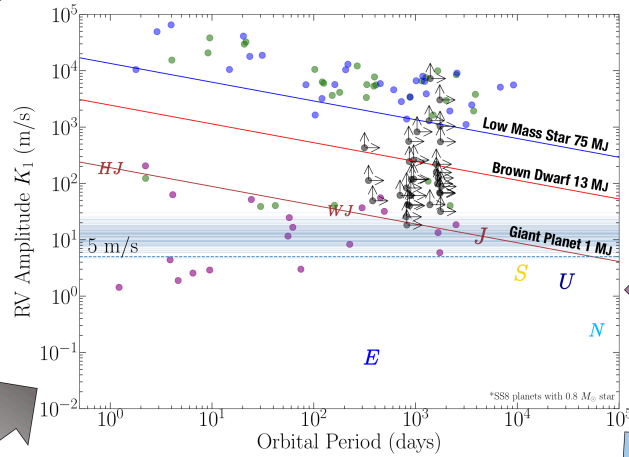
- Horizontal blue lines show the radial velocity residuals on **186 K dwarfs where no companions were detected**, and they are an estimation of our limiting precision with the CHIRON Spectrograph at CTIO 1.5m.



- 75% have Mean Absolute Deviations (MAD) less than **15 m/s, and down to 5 m/s**.



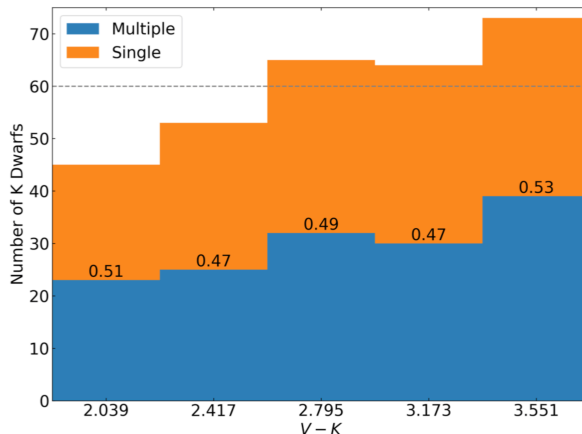
Orbital Architectures of 472 K dwarfs



Statistical Overview

- In the context of previous studies, the multiplicity rate for **G dwarfs is ~50%** (Raghavan+ 2010) and for **M dwarfs is ~27%** (Winters+ 2019).
- Combining our RV-speckle-wide companion survey on 300 K dwarfs, we find that **~49% of the K dwarfs host at least one companion** detected with any of the three techniques.
- There is a clear **absence of sub-stellar companions** detected at orbital periods < 300 days.
- **Hot Jupiters are found in about ~1% of the K dwarfs** of the total sample. Consistent with Gaidos+ 2016.

Stellar Multiplicity



SMARTS Telescopes

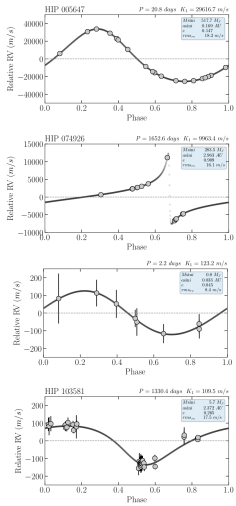
- At the 1.5m CTIO/SMARTS Telescope, the CHIRON high resolution spectrograph takes the data for the RV survey.
- CHIRON currently carries ~20 scientific programs per semester under the management of RECONS group. www.recons.org



- This effort has been supported by the NSF through AST-1910130 grant, and via observations made possible by the SMARTS Consortium

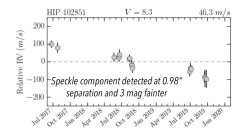
New Orbits Found!

- Now after **2.5 years surveying 300 stars** we have solved **31 orbits** of stellar, sub-stellar and planetary companions.
 - Periods ranging from ~2 days up to ~10 years.
 - Minimum masses from 0.6 M_J to 0.8 M_J.
 - Semi-major axis from 0.03 to 8.2 AU.



RV trends and Speckle

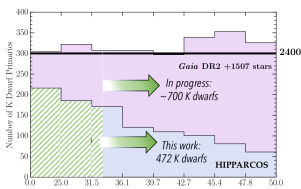
- On RV curves that only exhibit a steady constant change in velocity, Keplerian orbits are unlikely to fit. Therefore, we can only estimate a **minimum period and a minimum RV amplitude**.



- Our **speckle imaging survey³ done on all of these 472 K dwarfs** is providing detections of secondary components from **separations of ~10³'' to ~3''**, to determine if the RV trend is due to a wider companion or to a lower mass closer companion.

Volume-Complete Sample

- Our survey expanded from K dwarfs compiled with Hipparcos (blue) to a volume-complete sample of K dwarfs from Gaia DR2 (purple).



- We are currently advancing our survey a distance bin at a time, so partial results are still statistically significant.

[1] SB9: The ninth catalogue of spectroscopic binary orbits, Pourbaix D., Tokovinin A. et al. 2004, *Astronomy and Astrophysics*, 424, 727-732

[2] NASA Exoplanet Archive, California Institute of Technology.

[3] Multiplicity Survey of 1048 K dwarfs at Solar System Scales. Nusdeo, D., Henry, T., Horch, E., Paredes, L. et al. 2020, in preparation.