Scanning the population of planetary systems around stars with wide brown dwarf companions

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Motivation

Stars with wide brown dwarf companions that host exoplanets are extremely rare, as only four were reported to date. Different theories propose that planets can be significantly affected by wide companions through various processes involved. They can cause additional peculiarities observed in parameter distributions. Thus, these systems contain great potential and opportunities to enrich our knowledge about sub-stellar objects and test our concepts of planetary formation and evolution. However, the sample size is still too small to discuss even the most fundamental question: What is the fraction of such systems?

Spectroscopic observations

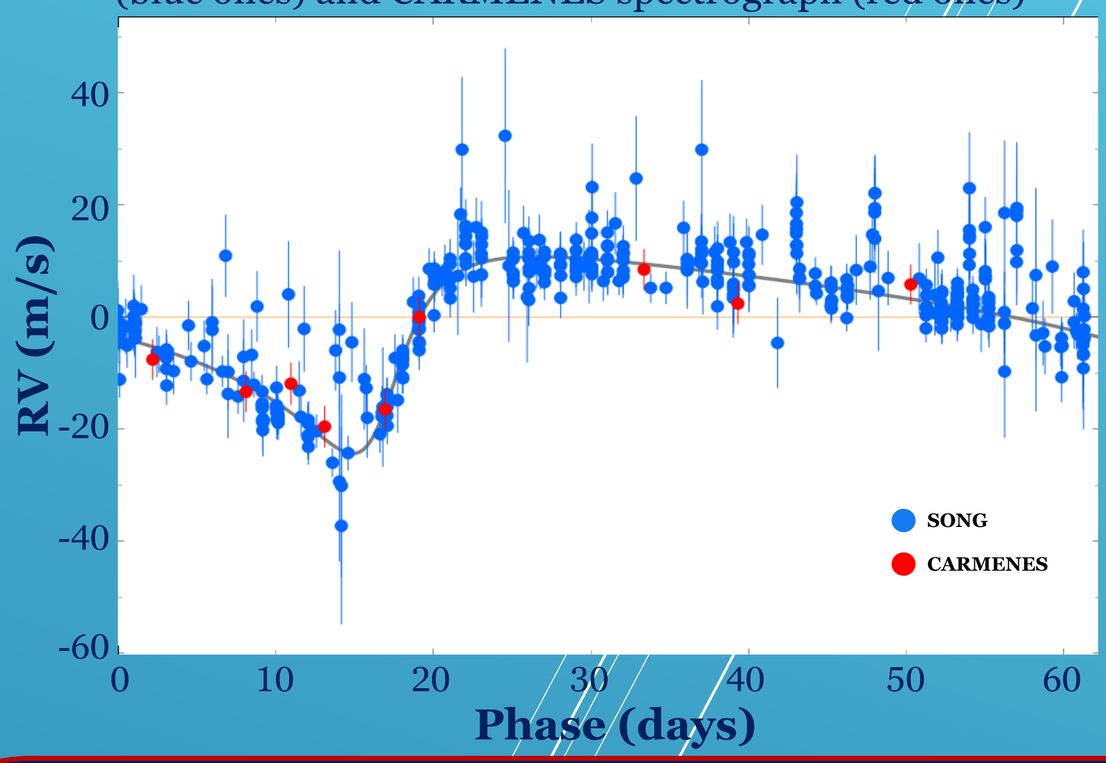
We searched the literature for wide co-moving systems with one sub-stellar component and a bright host suitable for intensive spectroscopic follow-up with the 1-m robotic Stellar Observations Network Group (SONG) telescope. Five systems were observed with SONG through a dedicated program.

One system was also observed with the STELLar Activity (STELLA) 1.2-m robotic telescopes to gauge the performance of the instrument.

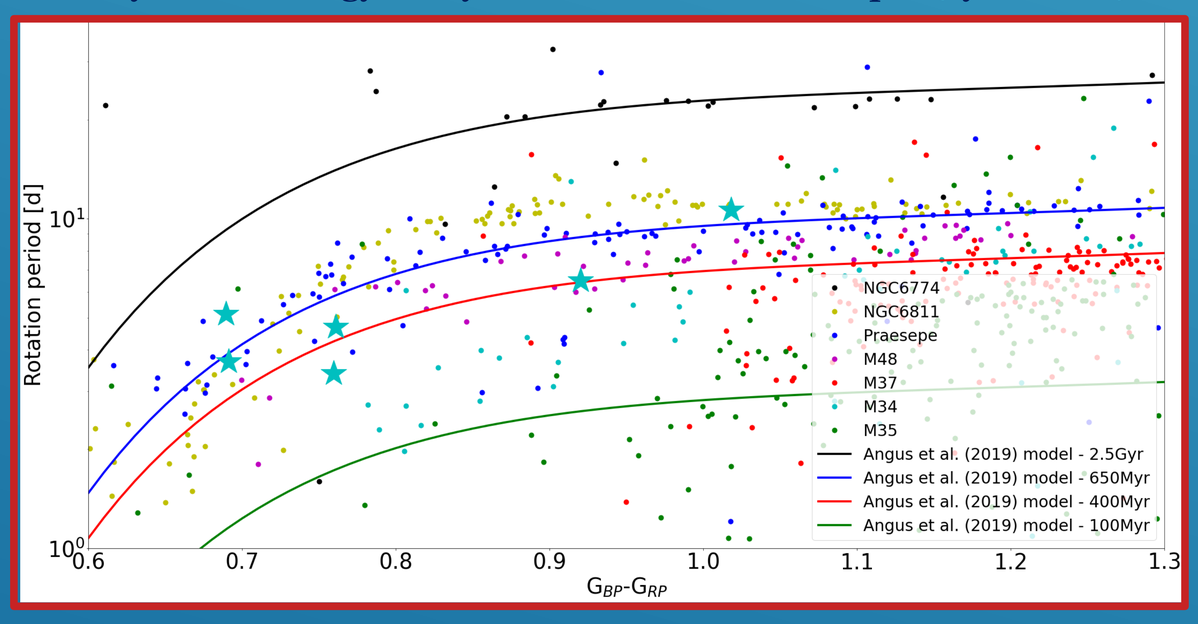
We additionally collected visible and near-infrared spectra for each system with the Calar Alto high-resolution search for M dwarfs with Exoearths with Near-infrared and optical Echelle Spectrographs (CARMENES).

The survey here explores five systems with a wide brown dwarf companion searching for exoplanets. One additional system with a confirmed exoplanet was used as a testbed, for which we recovered the orbital solution and improved the precision of derived parameters.

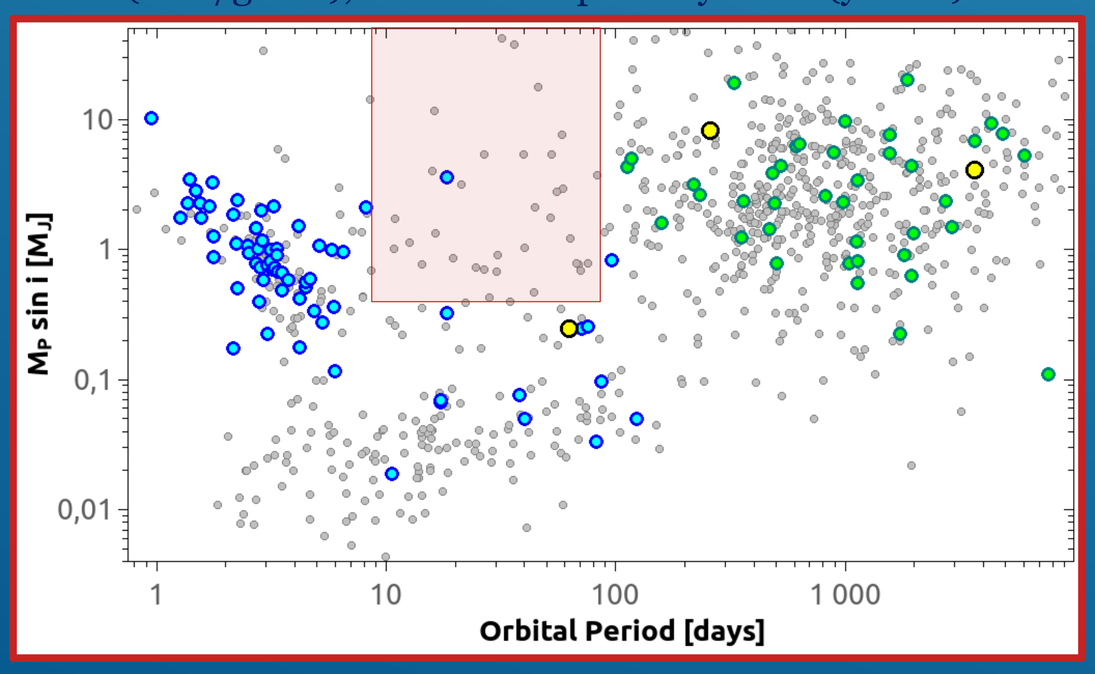
RVs of our testing system obtained with SONG spectrograph (blue ones) and CARMENES spectrograph (red ones)



Gyrochronology analysis for stars in our sample (cyan stars)



Minimum mass vs. Orbital period for single planet-host stars (grey points), planet-host stars with a stellar companion (blue/green), and our sample of systems (yellow)



Analysis

Analyzing periodograms of RVs and different activity indicators, we identified only one planetary candidate in our sample of five stars. We assigned the remaining signals in the periodograms to stellar activity.

We used MIST isochrones models to discuss the ages of stars. We then searched for the TESS LCs to derive stellar rotation periods used in gyrochronology analysis. Other age indicators used are also lithium equivalent width and X-ray luminosity.

We found our sample to be relatively young with four systems in order of hundreds of millions of years and two with ages about one Gyr. Given that wide brown dwarf companions become less luminous with age and their detection becomes more difficult, such a result is not surprising.

We used derived ages to derive the physical parameters of wide companions from several sub-stellar evolutionary models, and we confirmed brown dwarf nature for all companions besides one of them. The mass interval derived categorizes the object in this system as a giant planet.

Family of exoplanet-host stars with wide brown dwarf companions

Four systems of exoplanet-host stars with wide brown dwarf companions are known. However, one of them forms a hierarchical triple system with the binary companion, and we removed this system from future analysis.

We compared parameter distributions of our sample of three systems with distributions of single planet-host stars and with planet-host stars with wide stellar companions to study possible peculiarities. One such peculiarity found is the gap in the orbital period between 10-100 days for objects more massive than 0.4 M_J for systems with a stellar companion. They hence create visually two separate populations.

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