

# 20 years of CORALIE RVs measurements: the outer companions of Hot Jupiters

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## Context

**Hot Jupiters** were the first exoplanets discovered around main sequence stars, surprising us with their close-in orbits. They exemplify how exoplanets have challenged our understanding of **planetary system formation and evolution**. Despite over twenty years of study since the first hot Jupiter was found, there is still no consensus on their primary origin. Three main hypotheses for their formation have been proposed: **in situ formation, disk migration, and high-eccentricity tidal migration**. While no single hypothesis fully explains all the evidence, a combination of two major origin channels likely accounts for the characteristics of hot Jupiters and their relationships with other exoplanet populations. Since the early 2000s, we have been using the **CORALIE spectrograph** to monitor a few dozen hot Jupiters looking for outer companions to better understand their formation and evolution mechanisms.

## CORALIE spectrograph

CORALIE is a **fiber-fed echelle spectrograph** installed on the Swiss 1.2m Leonhard Euler Telescope at the La Silla Observatory of the European Southern Observatory (ESO) in Chile (Queloz et al. 2000; Udry et al. 2000).



**Fig. 1** - Euler Telescope ("Swiss") telescope in La Silla, Chile.

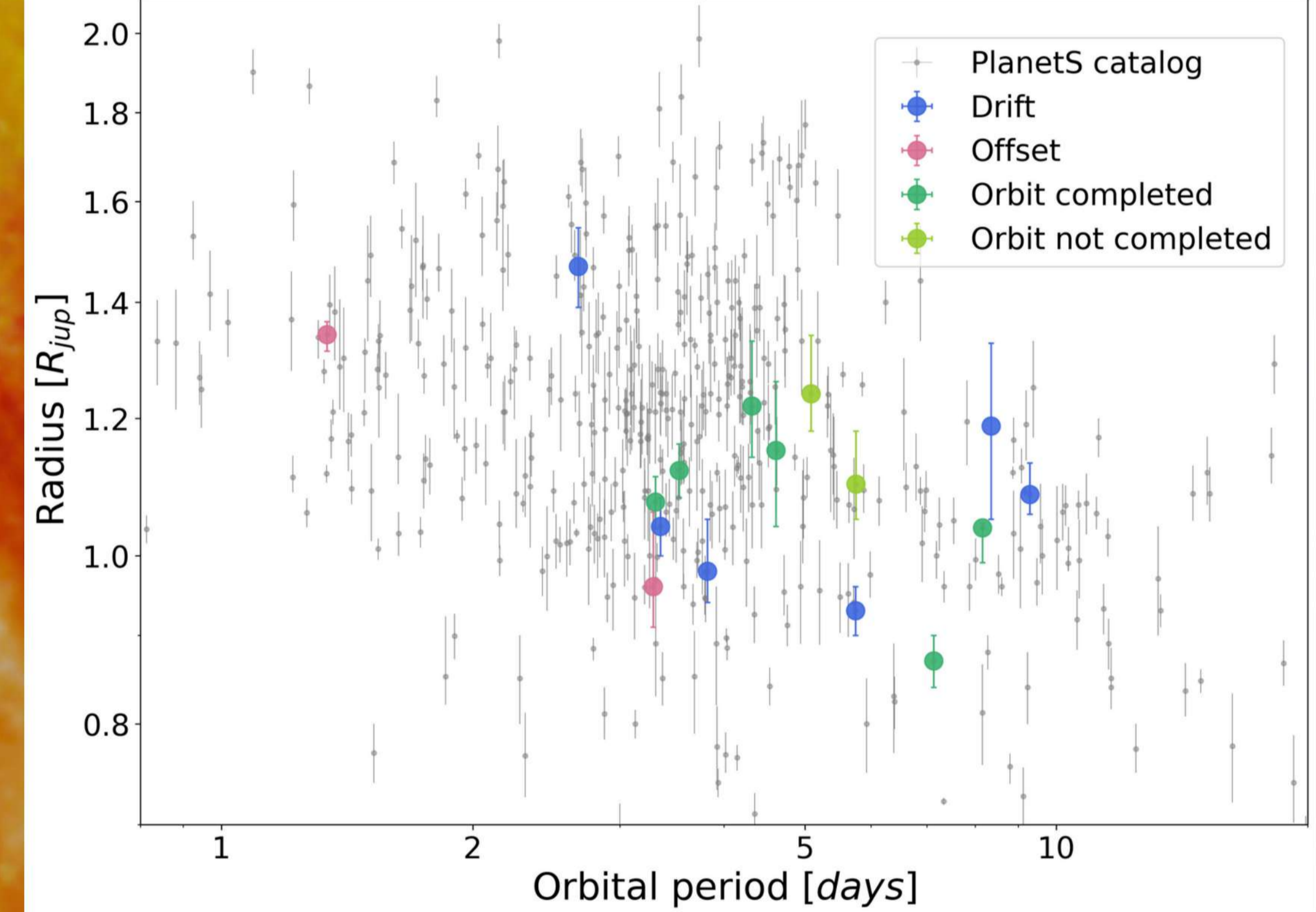
## Search for long-period companions of Hot Jupiters

Our search for **companions of Hot Jupiters** is based on the WASP confirmed planets observable from the Southern hemisphere. This search started after the first confirmations of WASP candidates with CORALIE. Originally, 111 targets were observed as part of this program. Today, only **16 targets** are being monitored. These targets are either companions with open/close orbits, linear drifts or targets with published additional companions that need more precise orbital parameters.

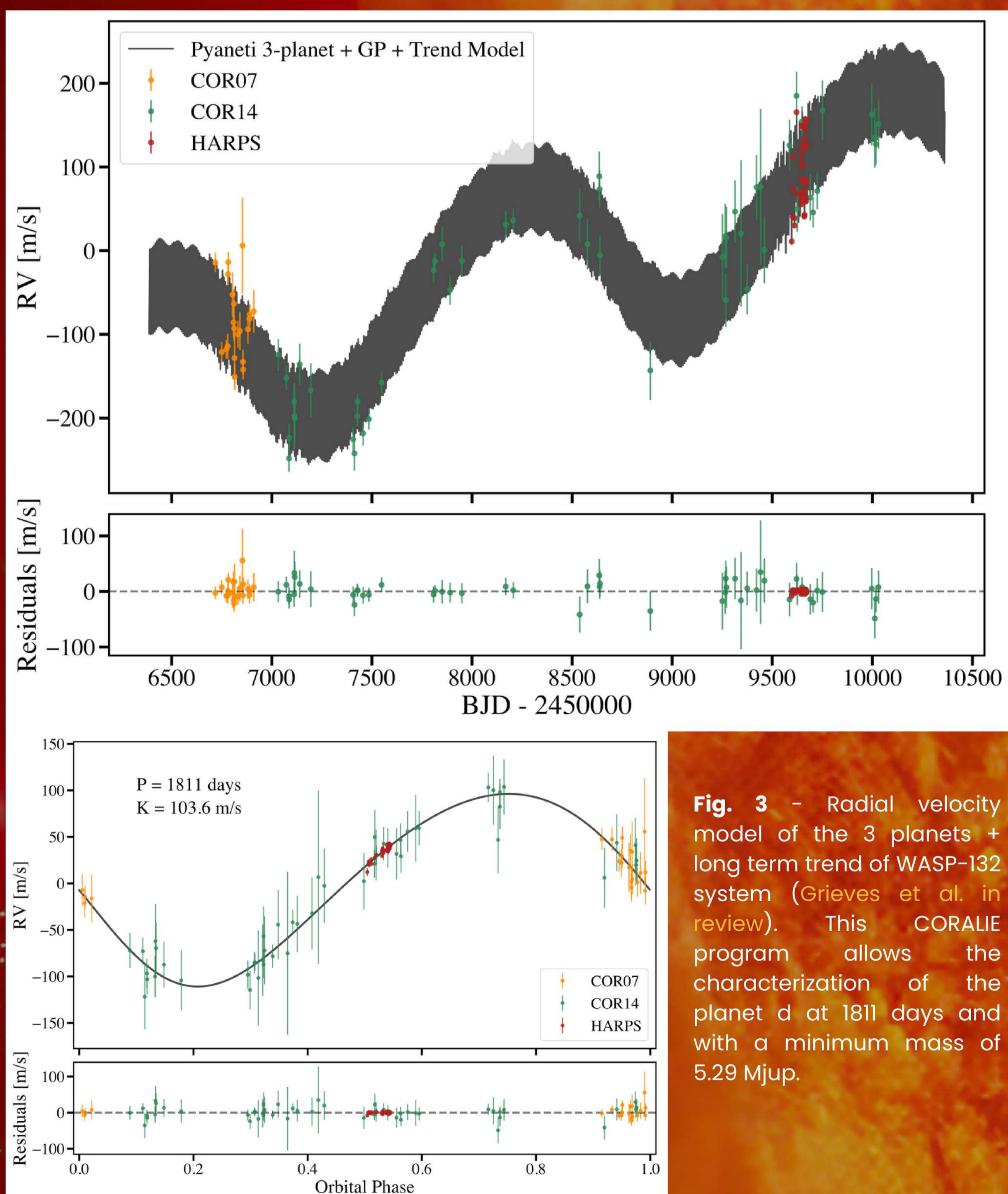
## Status of the survey

Among the 16 stars hosting a Hot Jupiter that are being monitored, **6 have a companion** with a close orbit, 2 have a clear companion with an open orbit, 6 show a long-term drift, and 2 exhibit an unclear offset between the two versions of CORALIE (before and after the fiber change in 2014) (see Fig. 2). Some outer companion from this program was already published: **WASP-41c and WASP-47c** (Neveu-vanMalle et al. 2016), or submitted: **WASP-132 system** (Grieves... Parc... et al. in review). 6 more systems with outer companions with orbital period from 2024 to 6104 days (=5.5 to 16.71 years) will be published in the coming months. We observe a **wide range of eccentricities** for the different hot-cold Jupiter pairs, which will enable us to study their formation and evolution scenarios. Moreover, these stars have now TESS data that we are planning to re-analyse in order to refine the ephemeris and parameters of the Hot-Jupiters. The new CORALIE data will also enable a refinement of the mass and eccentricity of the inner planet.

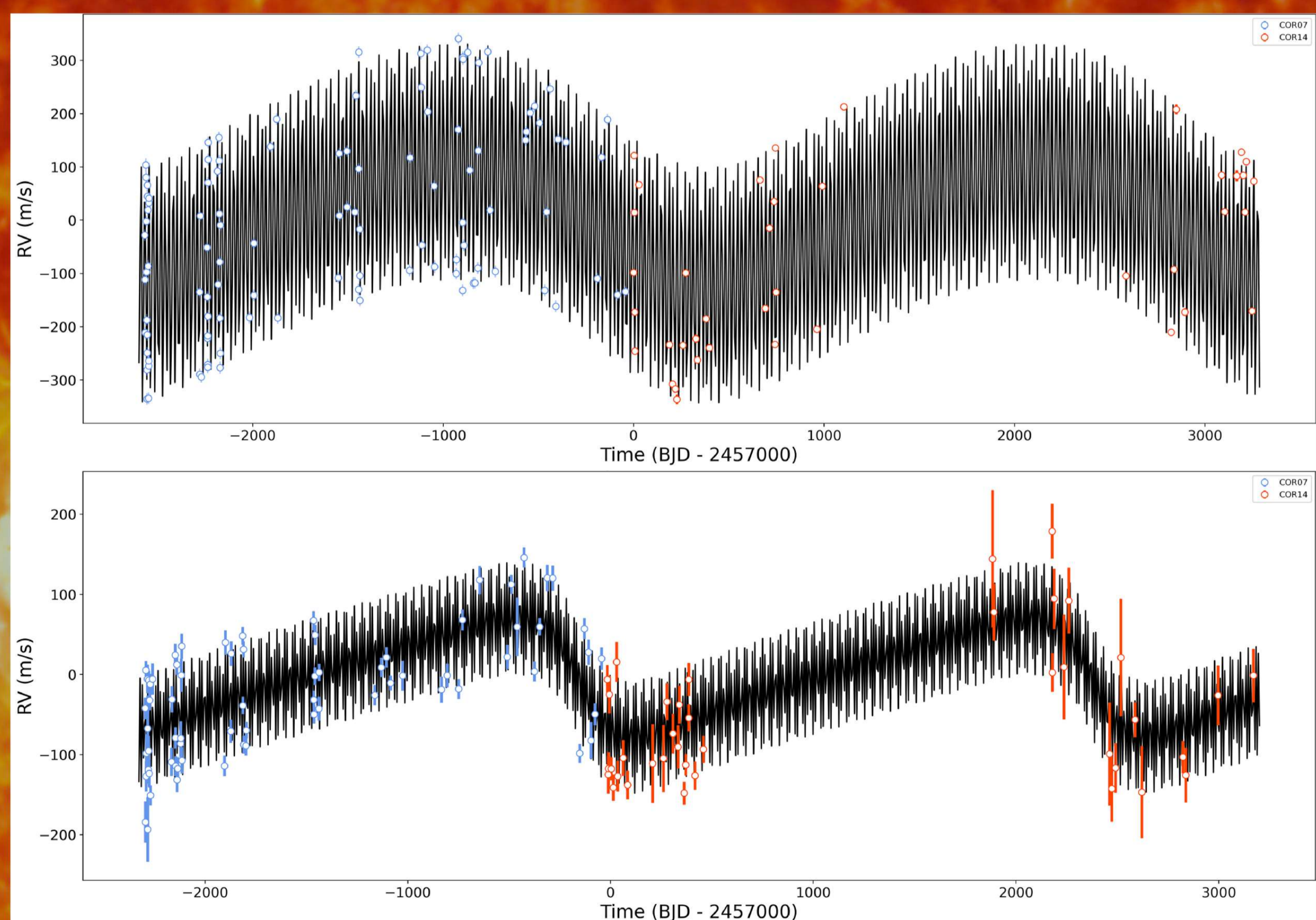
## Outer Companion status



**Fig. 2** - Hot Jupiters of the targets monitored colored by the status of the hint/detected of the outer companion of the system. In grey are the planets well-characterized (relative error in mass <25%, in radius <8%) from the PlanetS Catalog (<https://dace.unige.ch/exoplanets/>, Otegi et al. 2020, Parc et al. 2024).



**Fig. 3** - Radial velocity model of the 3 planets + long term trend of WASP-132 system (Grieves et al. in review). This CORALIE program allows the characterization of the planet d at 1811 days and with a minimum mass of 5.29 Mjup.



**Fig. 4** - 2 examples of the characterization of the orbit and minimum mass of 2 outer companions of a Hot-Jupiter: a 8.4 Mjup @ 3031 days with e=0.15 (upper panel) and a 4.75 Mjup @ 2533 days with e=0.46 (lower panel)

References: Queloz et al. 2000, A&A, 354  
Udry et al. 2000, A&A, 356  
Neveu-vanMalle et al. 2016, A&A, 586, A93  
Grieves et al. 2024, A&A, in review  
Otegi et al. 2020, A&A, 634, A43  
Parc et al. 2024, A&A, accepted