RADIAL VELOCITY SEARCH FOR LONG-PERIOD EXOPLANETS AND BROWN DWARFS WITH ELODIE AND SOPHIE

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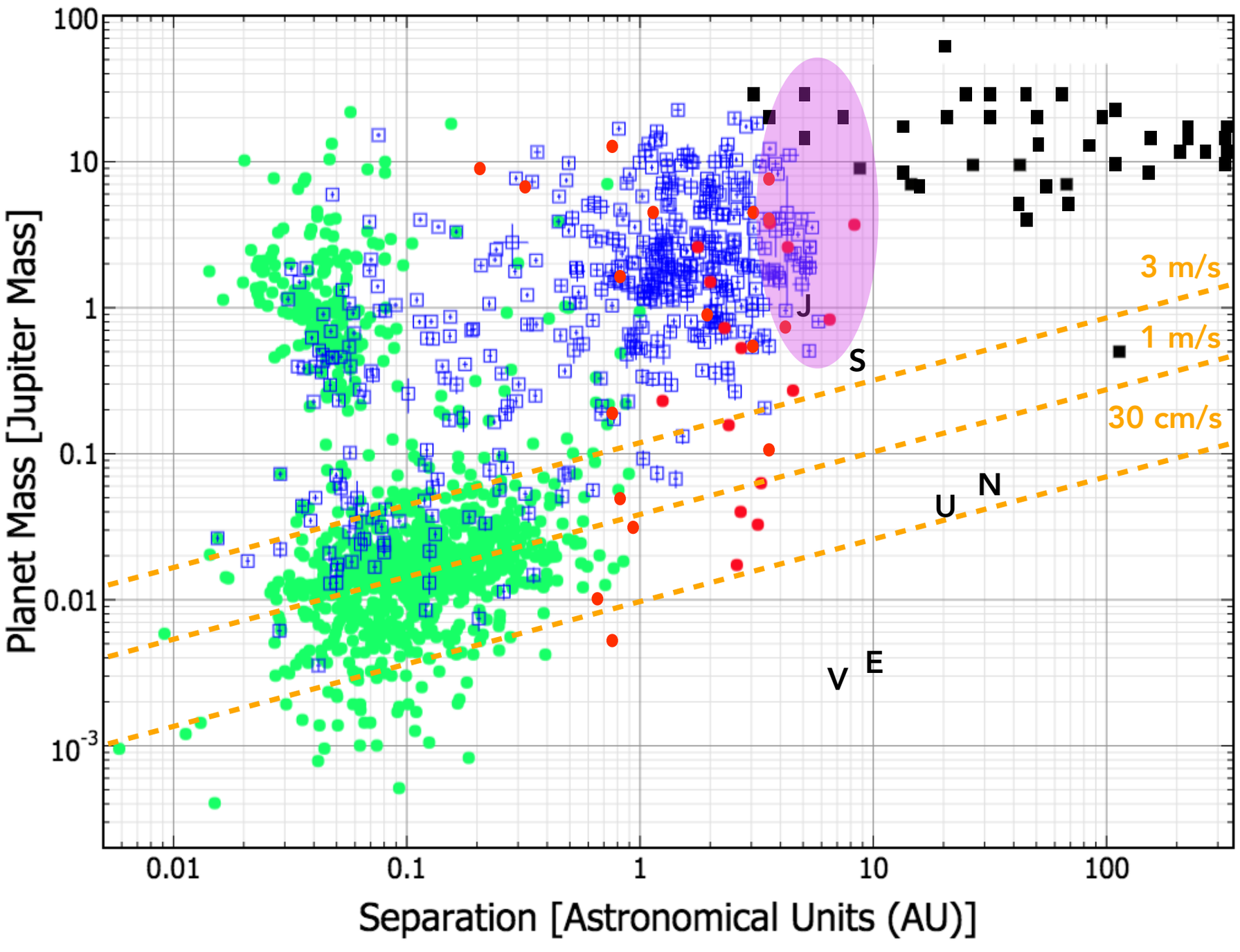
O. DEMANGEON

CONTEXT

A CURRENT VIEW OF LONG-PERIOD EXOPLANETS



RV

Imaging

Transit

Microlensing

41 systems with a>4AU detected using radial velocities

Info from exoplanet.eu, exoplanets.org and I. Boisse 2014

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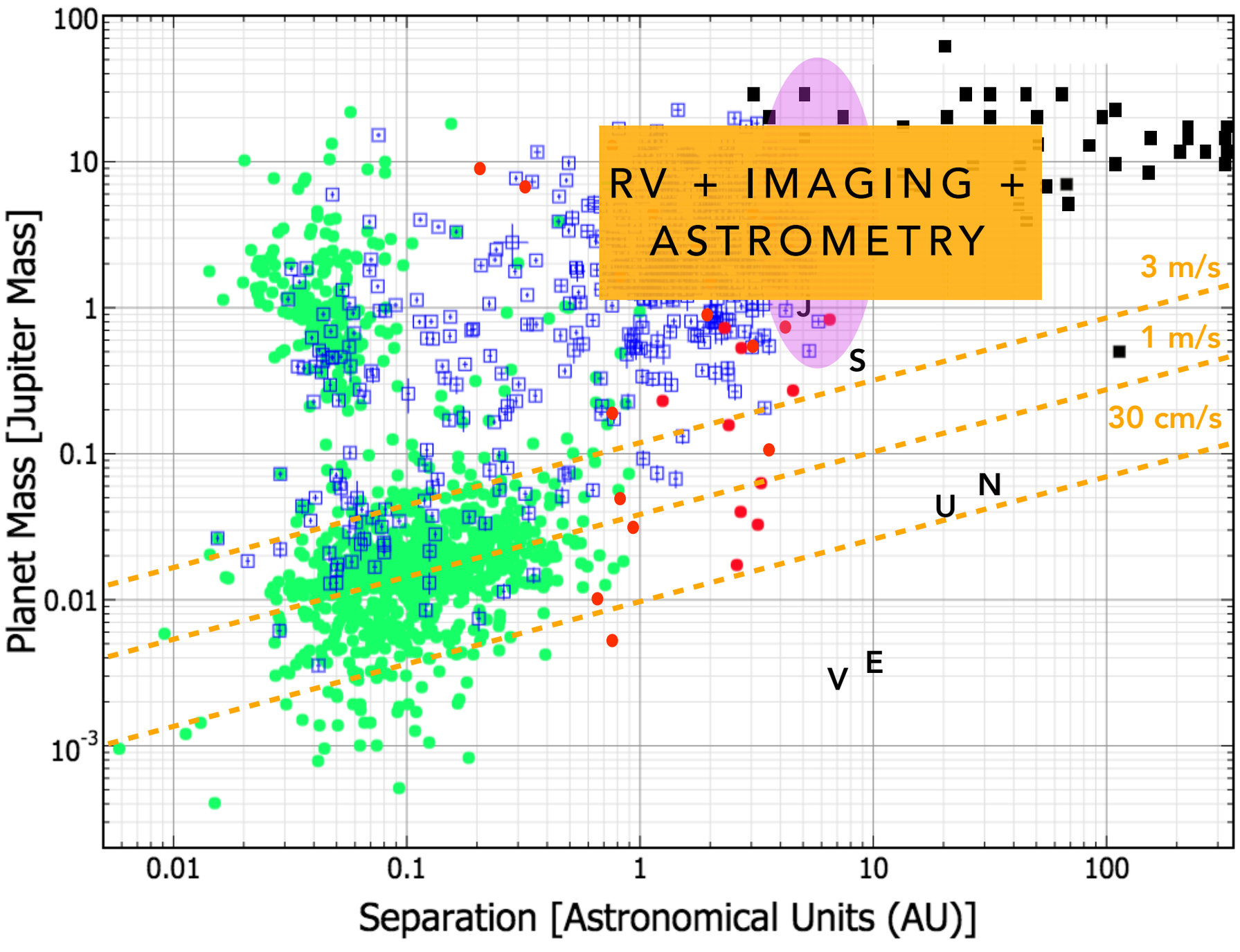

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CONTEXT

A CURRENT VIEW OF BROWN DWARFS

- No clear dividing line between very massive planets and brown dwarfs

- Only a few BD companions with orbital period larger than 10 years:

  - **4** CORALIE (Sahlmann et al. 2011), **1** HARPS (Lo Curto et al. 2010; Feroz et al. 2011), **5** ELODIE-SOPHIE (Bouchy et al. 2015, accepted)

- Number of BDs rises with the orbital period (Ma & Ge, 2014)

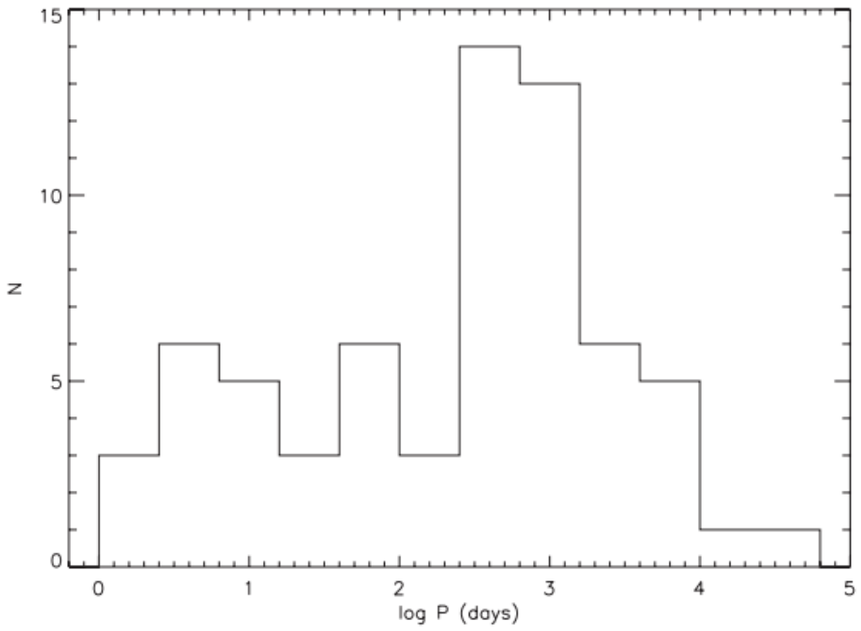


Figure 1. Period distribution of known BD companions around solar-type stars.

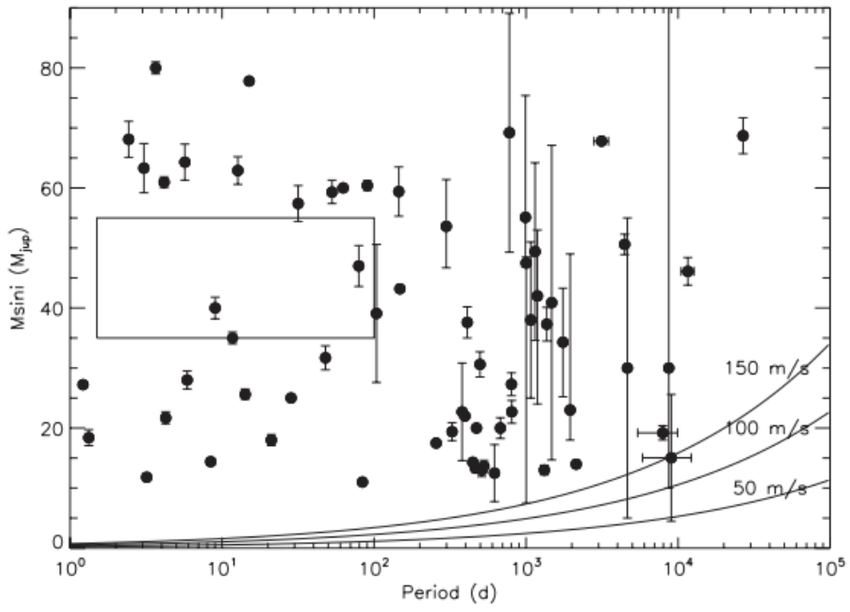


Figure 2. Cumulative mass distribution of BD candidates. Three lines with three RV precisions, 50, 100 and 150 m s^{-1}, are also shown.

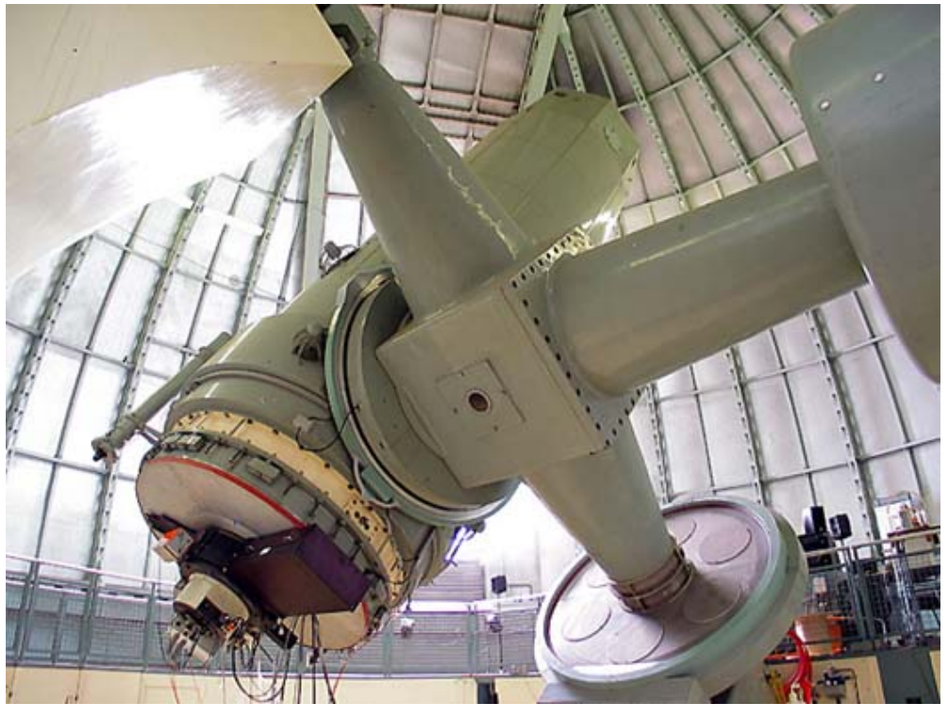
MA & GE, 2014

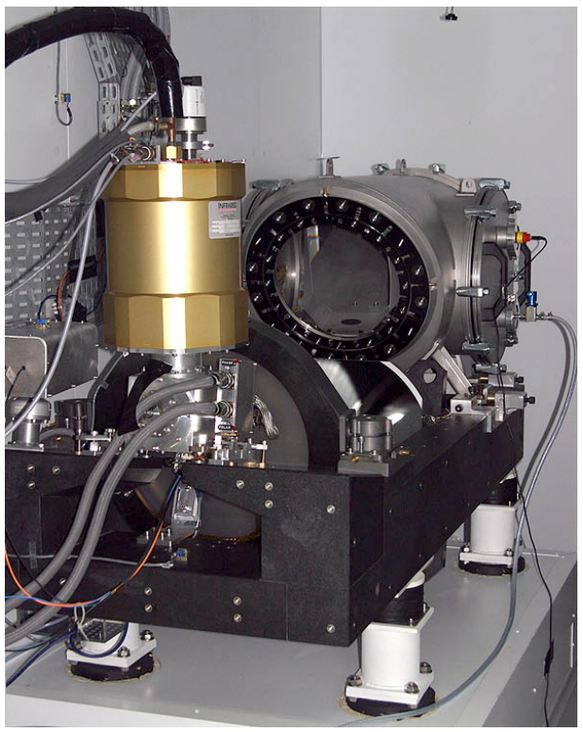
INSTRUMENTS

ELODIE & SOPHIE

- ELODIE 1994-2006
  - 51 Peg-b, in 1995, by Michel Mayor & Didier Queloz
  - Best precision ~ 7 m/s
- SOPHIE 2006-present
  - Two different spectral resolutions (HE and HR modes)
  - Precision down to 5-6 m/s with SOPHIE and 2 m/s with SOPHIE+, using simultaneous Thorium calibration.

193 CM TELESCOPE AT THE HAUTE PROVENCE OBSERVATORY, FRANCE

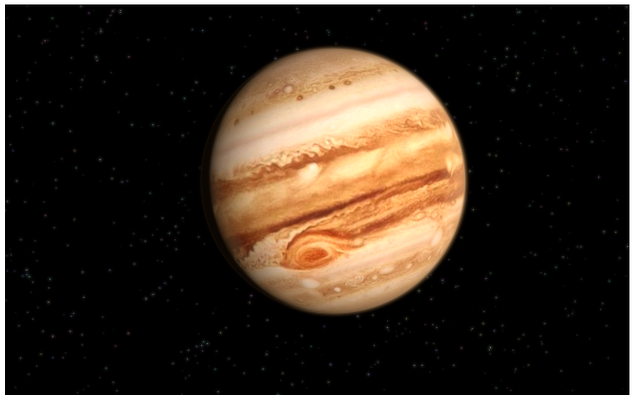




PROGRAMS

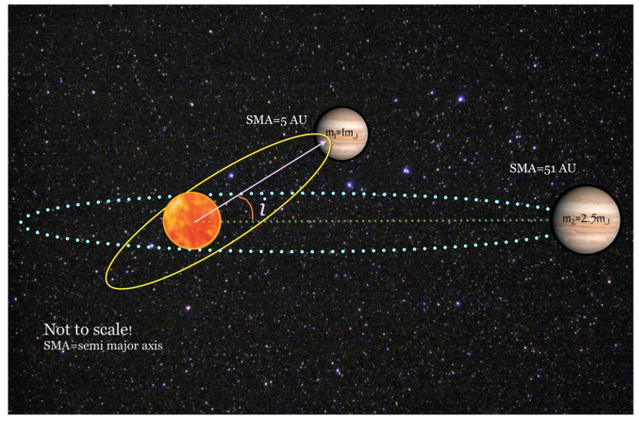
FOLLOW-UP OF ELODIE LONG PERIODS

- Long-period exoplanets and brown dwarfs
- Historical ELODIE catalog
- ~60 targets, G and K stars
- +20 years of data
- Allows us to look for giant planets at a>5 AU



LONG-TERM FOLLOW-UP OF KNOWN TRANSITING HOT JUPITERS

- Orbital evolution of hot Jupiters:
→ Possible interaction with another companion
- Few cases of transiting hot Jupiters in multi- planetary systems with long-period giant planets
- ~35 targets (CoRoT, Kepler, HAT, WASP)



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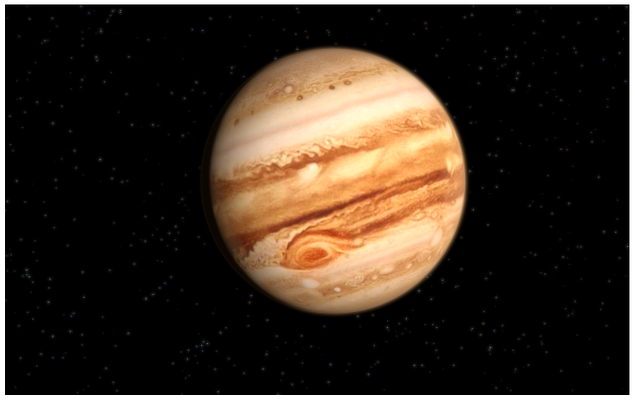

COMPLEMENTARY TO SIMILAR PROGRAMS IN THE SOUTH

LONG-TERM FOLLOW-UP OF KNOWN TRANSITING HOT JUPITERS

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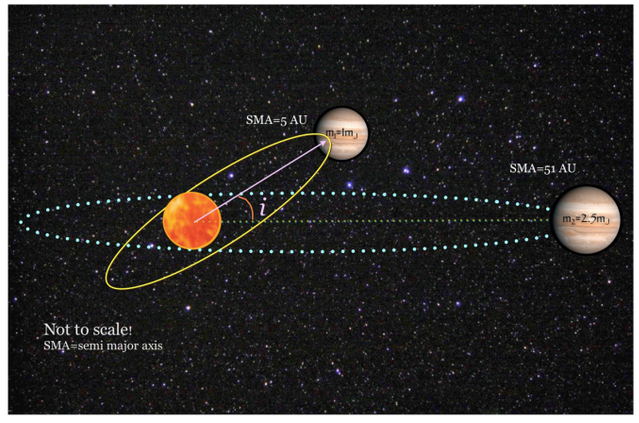


PROGRAMS

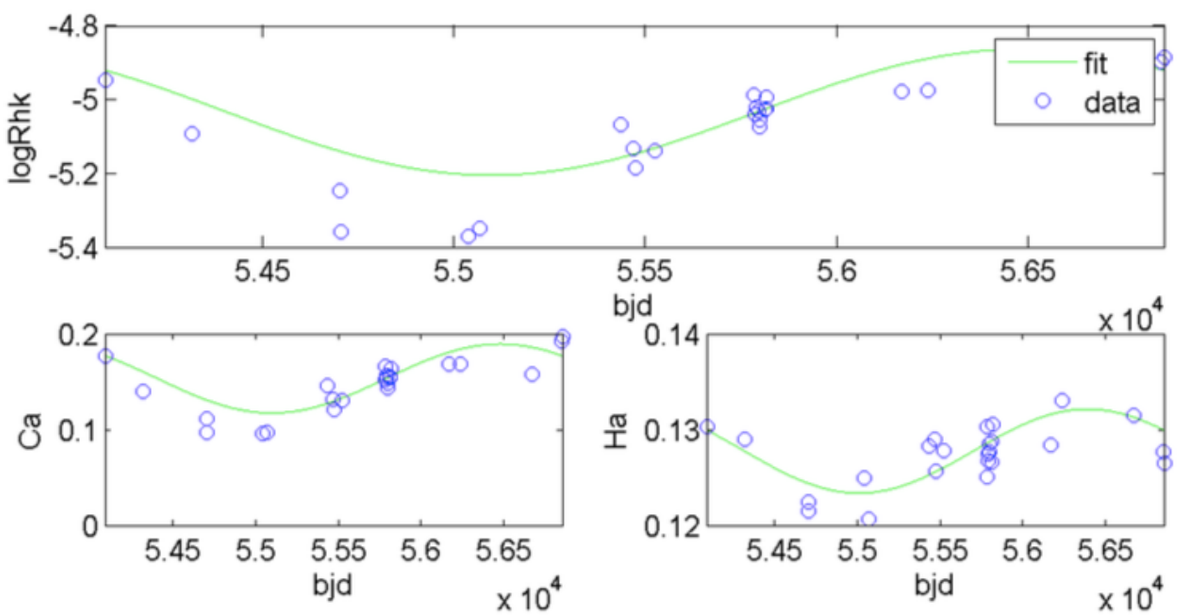
WHEN DEALING WITH LONG-PERIOD EXOPLANETS, WE MUST CONSIDER:

- Instrumental drifts & offsets
  - Offset between ELODIE, SOPHIE and SOPHIE+ data
  - Long-term variations in RVs due to instrumental effects

FOLLOW-UP OF CONSTANT STARS (B. COURCOL)

- Magnetic cycles
  - Correlations with activity index (log R'_{HK}) and CCF parameters (bisector, FWHM, contrast)
  - Evolution of activity indices (Ca II and Hα lines)

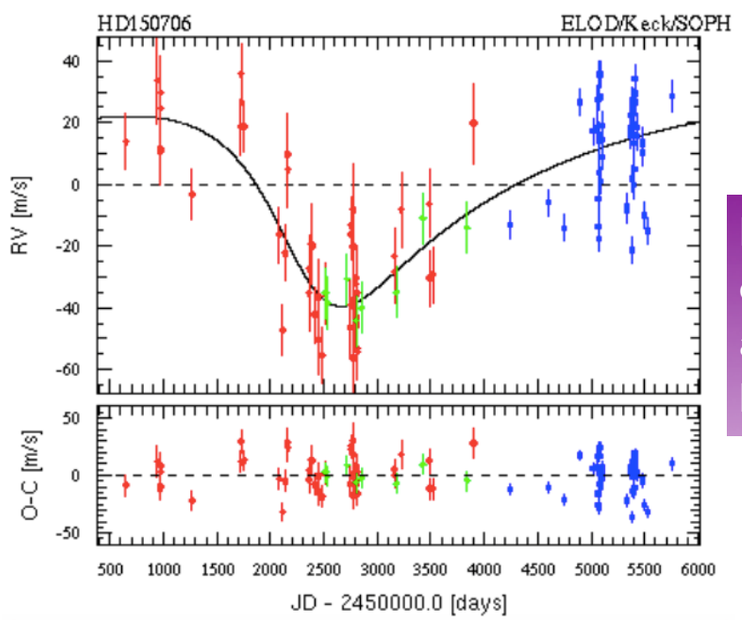
ACTIVITY INDICES (I. BOISSE & O. GIRAULT)



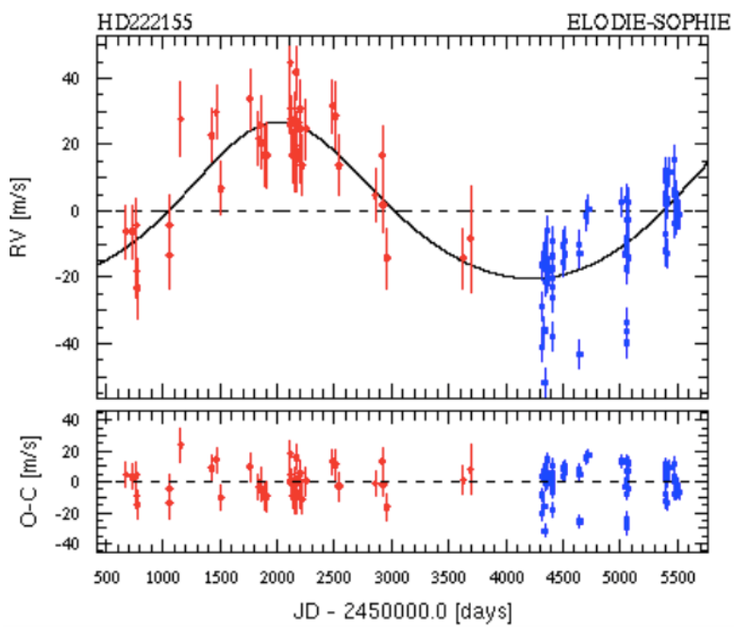
RESULTS

FOLLOW-UP OF ELODIE LONG PERIODS

BOISSE ET AL. 2012

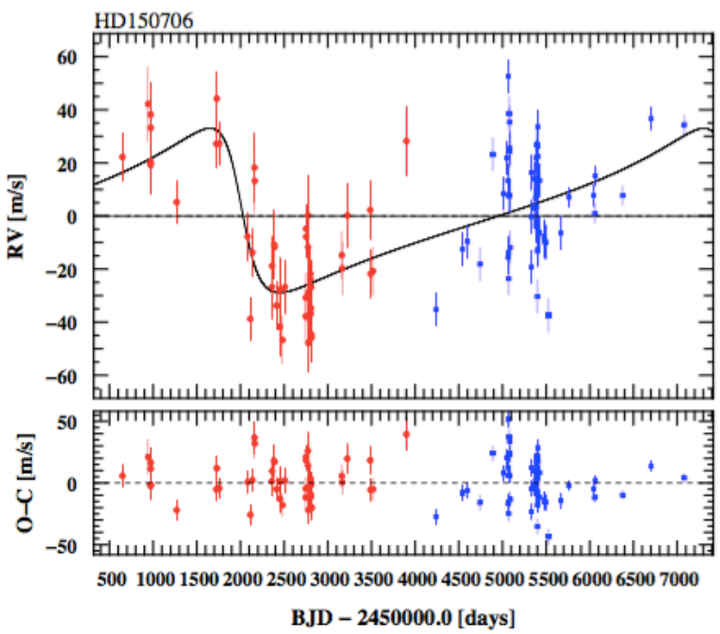


P [days] = 5894^{+5584}_{-1498}
e = $0.38^{+0.28}_{-0.32}$
a [AU] = $6.7^{+4.0}_{-1.4}$
Mp sin i [MJup] = $2.71^{+1.14}_{-0.66}$

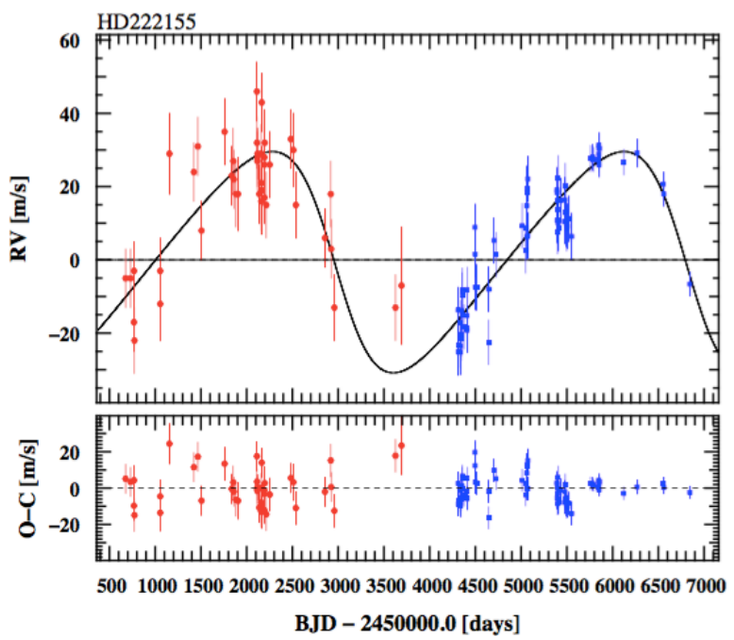


P [days] = 3999^{+469}_{-541}
e = $0.16^{+0.27}_{-0.22}$
a [AU] = $5.1^{+0.6}_{-0.7}$
Mp sin i [MJup] = $1.90^{+0.67}_{-0.53}$

UPDATED ORBITS



P [days] = 5655 ± 904
e = 0.6 ± 0.1
a [AU] = 6.2
Mp sin i [MJup] = 2.16

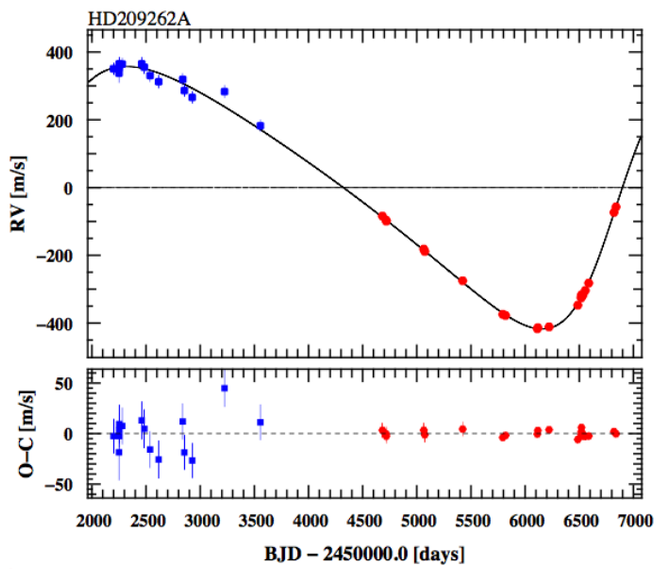


P [days] =3841 ± 54
e = 0.25 ± 0.06
a [AU] = 4.8
Mp sin i [MJup] = 2.25

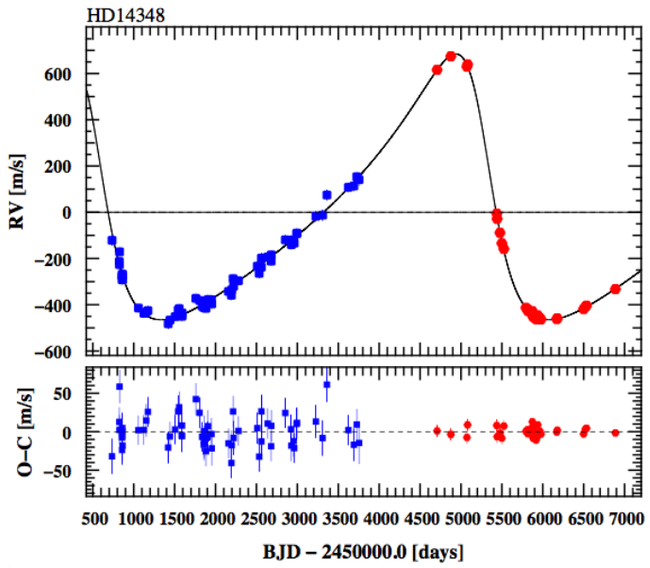
RESULTS

FOLLOW-UP OF ELODIE LONG PERIODS

BOUCHY ET AL. 2015, ACCEPTED

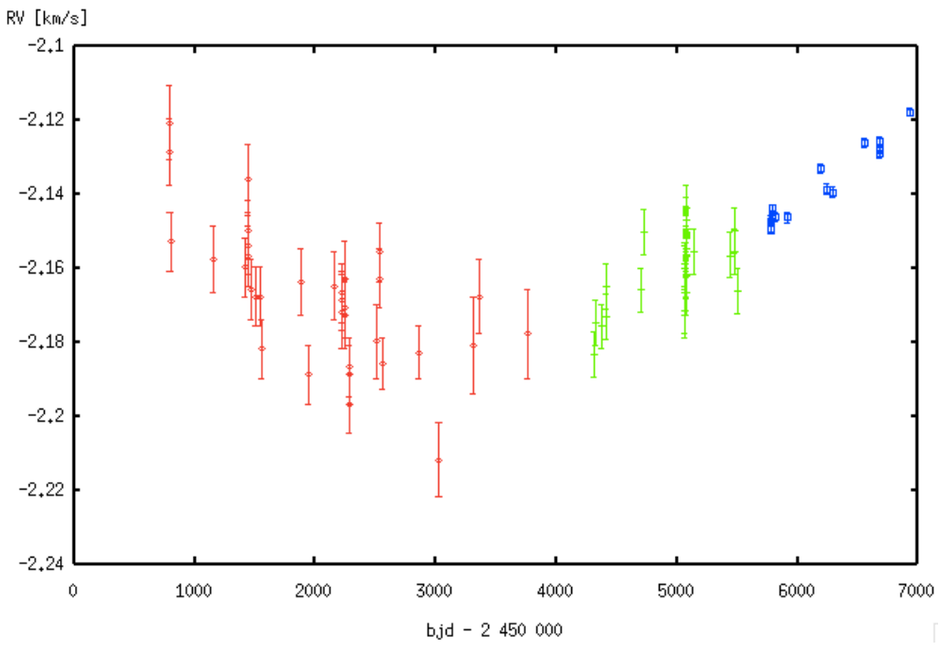


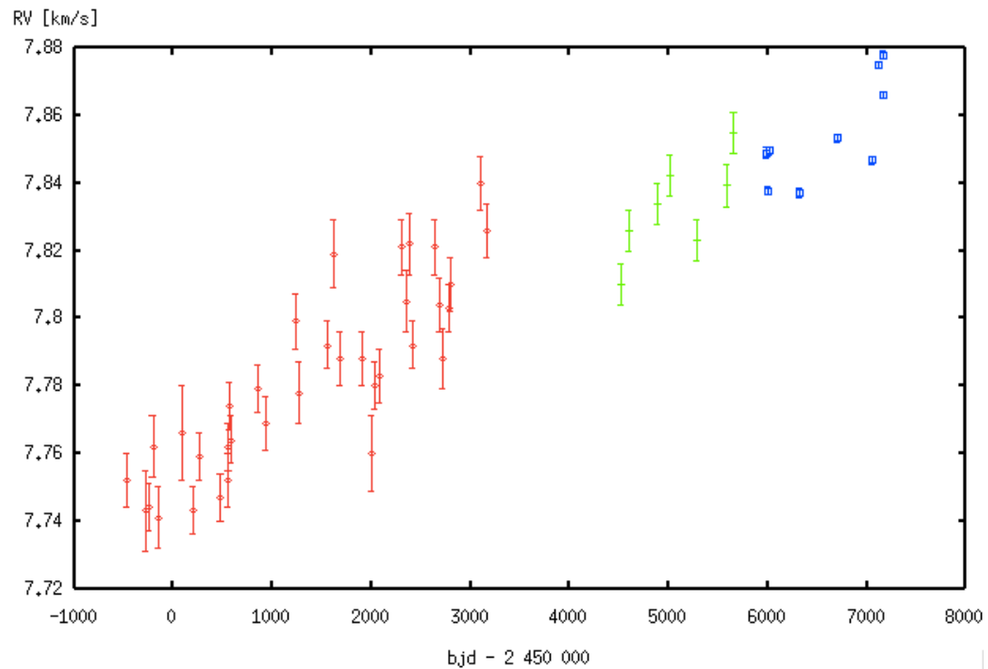
P [days] = 5405 ± 81
e = 0.344 ± 0.007
a [AU] = 6.1
Mc sin i [MJup] = 31.8



P [days] = 4743.6 ± 5.6
e = 0.455 ± 0.004
a [AU] = 5.9
Mc sin i [MJup] = 47.8

INTERESTING CASES IN THIS PROGRAM

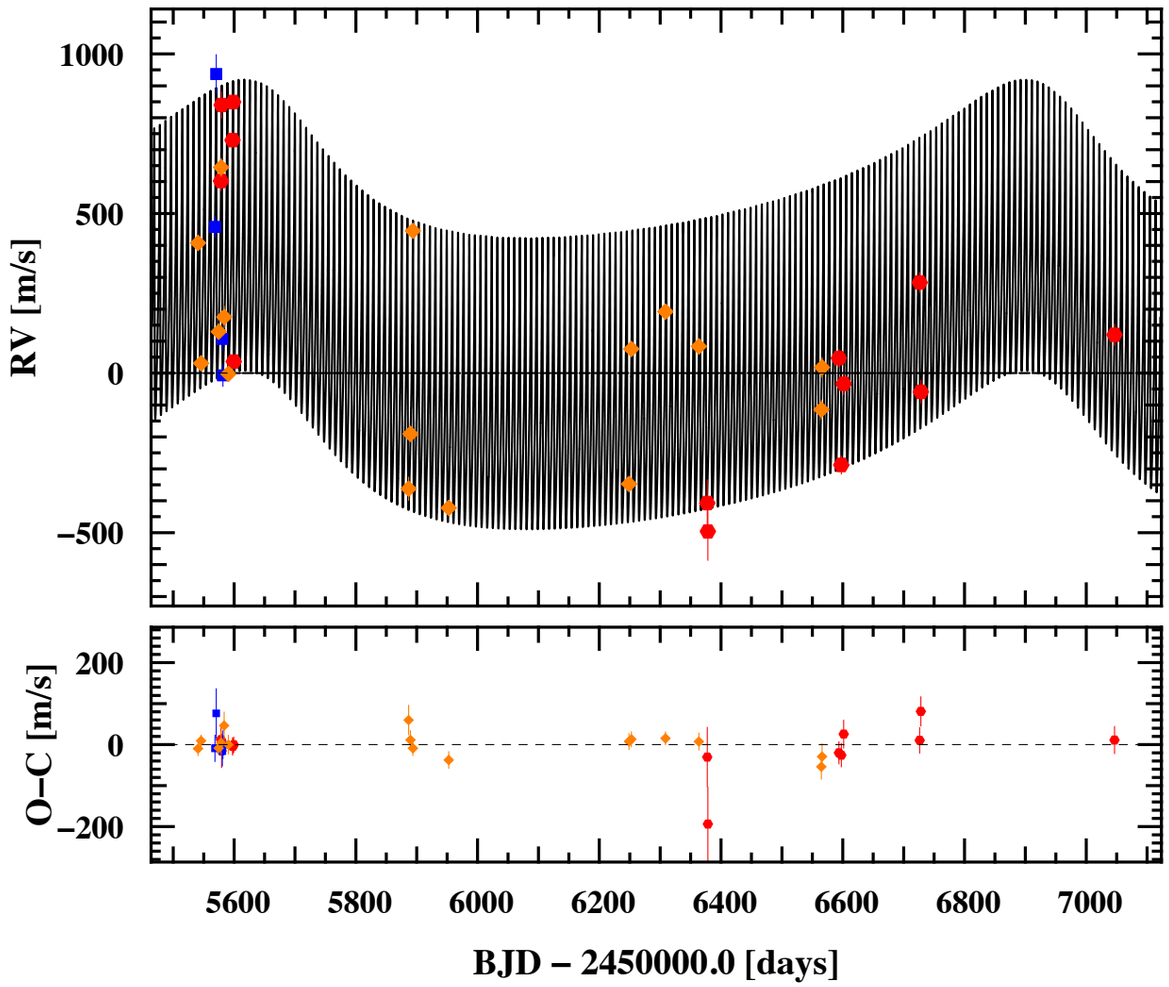


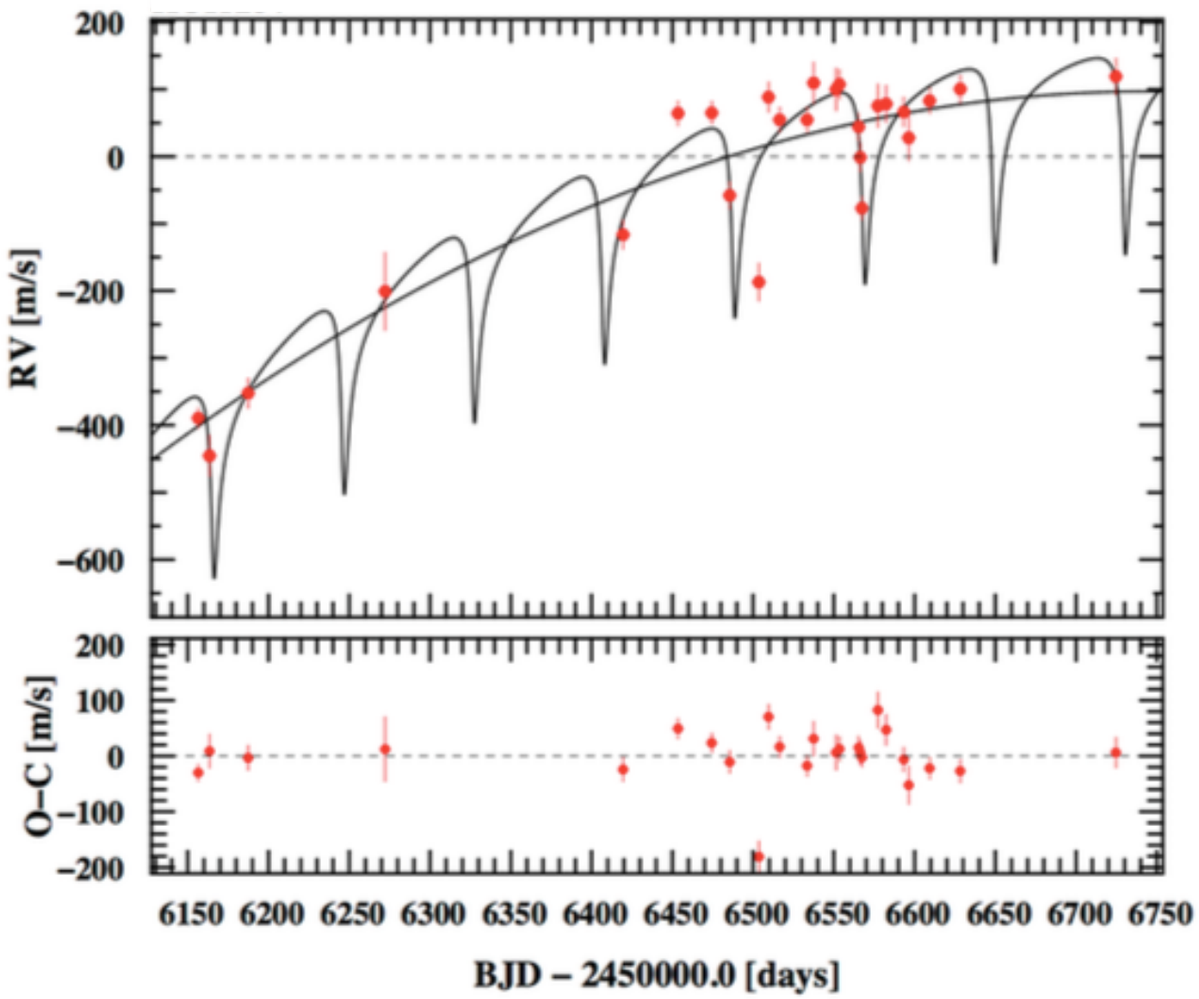


RESULTS

LONG-TERM FOLLOW-UP OF KNOWN TRANSITING HOT JUPITERS

PRELIMINARY RESULTS



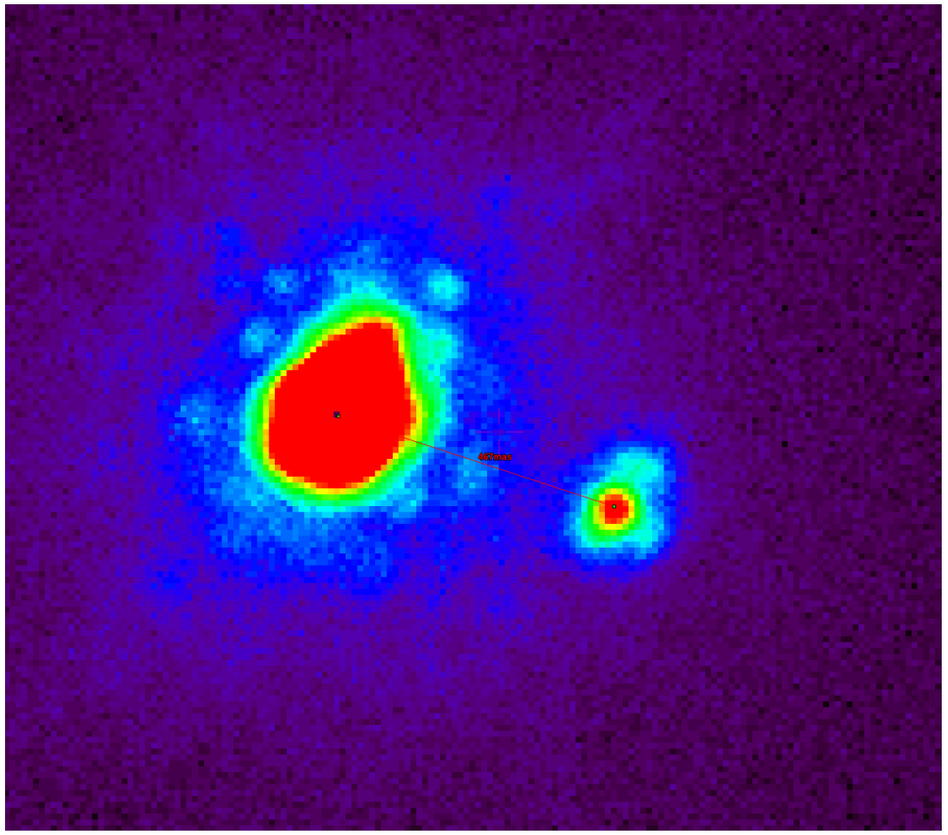


RESULTS

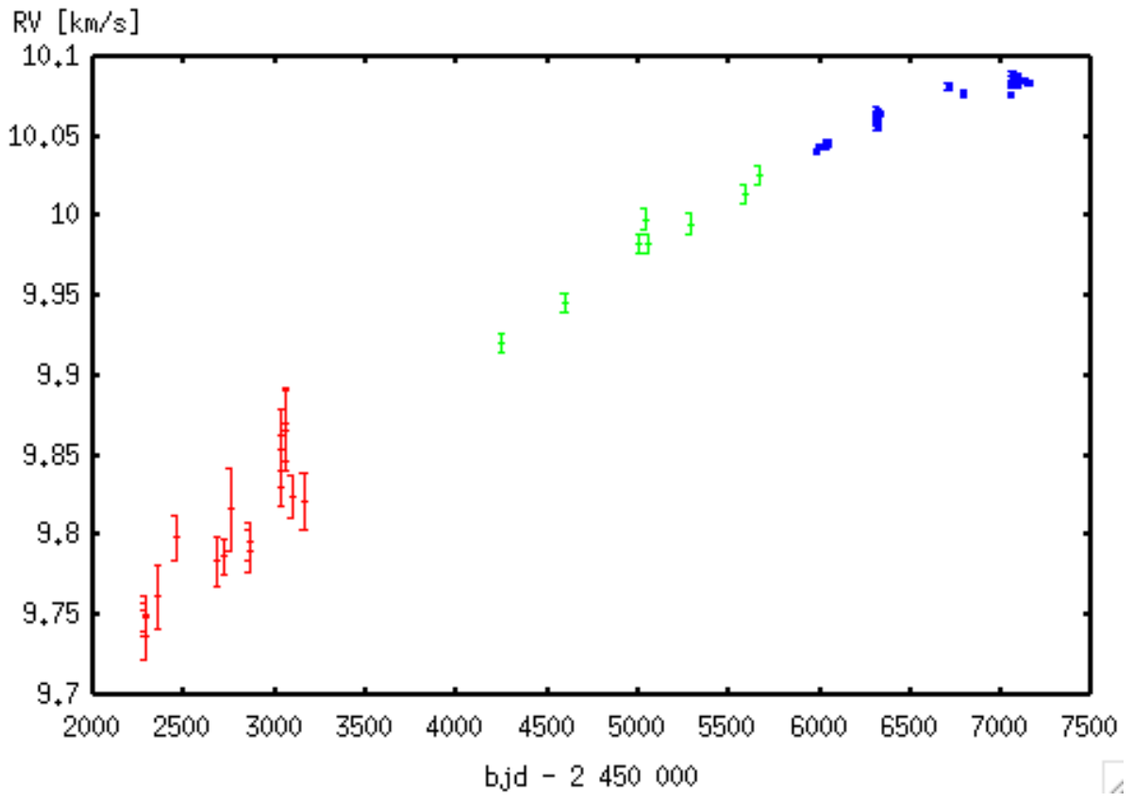
FOLLOW-UP OF ELODIE LONG PERIODS

- Synergy with Direct Imaging
  - Collaboration with J. Hagelberg (University of Hawai'i)
  - Subaru / SCExAO

H-BAND IMAGE – SEPARATION 0.4"



RADIAL VELOCITIES: ELODIE, SOPHIE, SOPHIE+



DISCUSSION & CONCLUSIONS

- The search for long-period planets and BDs is biased by the relatively **small number of long term surveys**

- Our recent results **double** the number of known BD companions with orbital period **longer than 10 years**

- This helps to set up a better observational base with which to compare models and theories of formation and evolution of BDs

- RV measurements do not constrain the orbital inclination, so we have only the **minimum mass**. We need complementary observational constraints to determine the true mass or to exclude the stellar nature of the companion. These companions are excellent candidates for **astrometry** and **direct imaging**

- The separation between planets and BDs may be related not only to the mass, but also the **formation scenario**. Statistical properties of BD companions should permit to distinguish between different formation and evolution models