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

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A CURRENT VIEW OF LONG-PERIOD EXOPLANETS

41 systems with $a>4$AU detected using radial velocities

Info from exoplanet.eu, exoplanets.org and I. Boisse 2014
A CURRENT VIEW OF LONG-PERIOD EXOPLANETS

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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)
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.
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)
PROGR.AMS

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COMPLEMENTARY
TO SIMILAR
PROGRAMS IN THE
SOUTH
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
- Magnetic cycles
- Correlations with activity index ($\log R'_{\text{HK}}$) and CCF parameters (bisector, FWHM, contrast)
- Evolution of activity indices (Ca II and H\(\alpha\) lines)

FOLLOW-UP OF CONSTANT STARS (B. COURCOL)

ACTIVITY INDICES (I. BOISSE & O. GIRAULT)
FOLLOW-UP OF ELODIE LONG PERIODS

RESULTS

BOISSE ET AL. 2012

P [days] = 5894
\[ \pm 5584 \]
e = 0.38
a [AU] = 6.7
Mp sin i [MJup] = 2.71

P [days] = 3999
\[ \pm 469 \]
e = 0.16
a [AU] = 5.1
Mp sin i [MJup] = 1.90

UPDATED ORBITS

P [days] = 5655 ± 904
\[ \pm 1498 \]
e = 0.6 ± 0.1
a [AU] = 6.2
Mp sin i [MJup] = 2.16

P [days] = 3841 ± 54
\[ \pm 114 \]
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

\[ P \text{ [days]} = 4743.6 \pm 5.6 \]
\[ e = 0.455 \pm 0.004 \]
\[ a \text{ [AU]} = 5.9 \]
\[ M_c \sin i \text{ [MJup]} = 47.8 \]

\[ P \text{ [days]} = 5405 \pm 81 \]
\[ e = 0.344 \pm 0.007 \]
\[ a \text{ [AU]} = 6.1 \]
\[ M_c \sin i \text{ [MJup]} = 31.8 \]

INTERESTING CASES IN THIS PROGRAM

\[ P \text{ [days]} = 4743.6 \pm 5.6 \]
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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