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

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OHP 2015 : TWENTY YEARS OF GIANT EXOPLANETS
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
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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)
**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)
PROGRAMS

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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 ($\log R'_{HK}$) 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)
WHEN DEALING WITH LONG-PERIOD EXOPLANETS, WE MUST CONSIDER:

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Radial velocities

$H\alpha$ index

$H\alpha$: As Gomes da Silva et al. 2013, $\delta \lambda_{H\alpha} = 0.678$ nm
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- Magnetic cycles

$\delta\lambda_{H\alpha} = 0.678$ nm
RESULTS

FOLLOW-UP OF ELODIE LONG PERIODS

BOISSE ET AL. 2012

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

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

UPDATED ORBITS

\[ P [\text{days}] = 5655 \pm 904 \]
\[ e = 0.6 \pm 0.1 \]
\[ a [\text{AU}] = 6.2 \]
\[ M_p \sin i [\text{MJup}] = 2.16 \]

\[ P [\text{days}] = 3841 \pm 54 \]
\[ e = 0.25 \pm 0.06 \]
\[ a [\text{AU}] = 4.8 \]
\[ M_p \sin i [\text{MJup}] = 2.25 \]
RESULTS

FOLLOW-UP OF ELODIE LONG PERIODS

BOUCHY ET AL. 2015, ACCEPTED

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

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

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.