HARPS-N and SOPHIE joint follow-up of *Kepler* planetary candidates

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References

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Damiani, C., et al. 2015, A&A, 574, A39
Fressin, F., et al. 2013, ApJ, 766, 81
Hébrard, G., et al. 2013, A&A, 554, A114
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Abstract

Radial velocity follow-up is mandatory to establish the nature of most of the transiting planet candidates detected with *Kepler*, then to characterize them and in particular to measure their mass and eccentricity. We started follow-up programs with the spectrograph HARPS-N that benefit from our SOPHIE observations on *Kepler* Objects of Interest. The goal of our HARPS-N programs is mainly to extend the SOPHIE results toward *Kepler* planetary candidates having lower masses, smaller radii, and/or fainter host stars.


Kepler
SOPHIE@OHP-193
HARPS-N@TNG

Velocimetry of *Kepler* transit candidates to:

1. Establish the planetary nature of the Kepler Objects of Interest (KOIs).
   - False Positive Rate is significant for close-in, giant KOIs: 34.8 ± 6.5 % (Santerne et al. 2012) or 29.3 ± 3.1 % (Fressin et al. 2013).
   - Even larger FPR at longer periods?
2. Measure these False Positive Rates.
3. Measure the mass and the eccentricity of the validated planets.
4. Search for additional, non-transiting planets in the systems.

There are the goals of our SOPHIE follow-up of KOIs.
But SOPHIE has some limitations ➔ Complement with HARPS-N

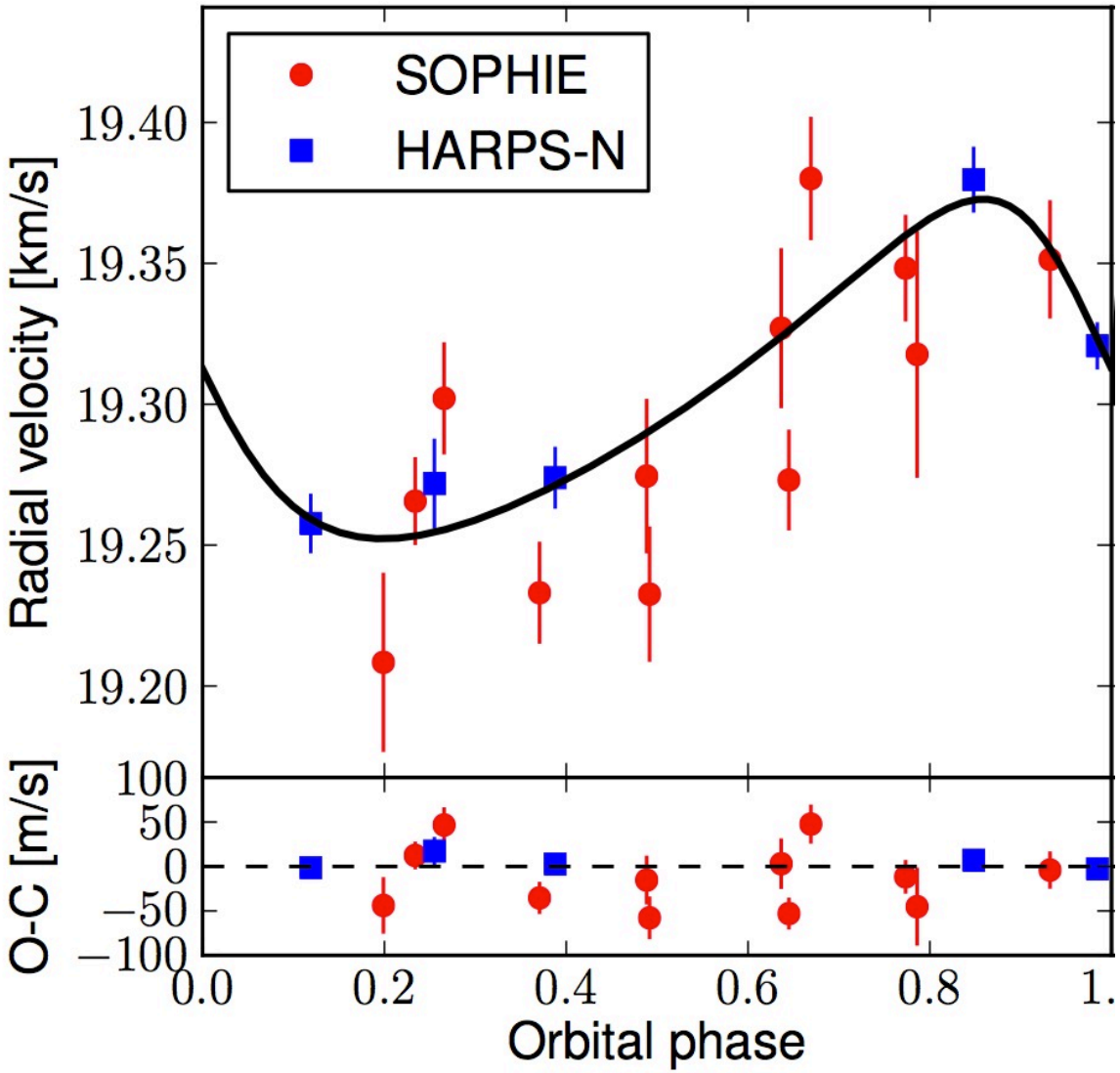
	SOPHIE	HARPS-N
Telescope	1.93-m at OHP (France)	3.58-m at TNG (Canary)
First light	2006	2012
Fed	Two optical fibers with octagonal sections	
Aperture	3”	1”
Thermally-controlled	Dispersive components in a constant-pressure tank	Whole instrument in a vacuum vessel
λ / Δλ	75,000 or 40,000	115,000
λ range	~ 385 - 693 nm	
λ calibration	Thorium-argon lamps	
RV measurements	Cross-correlation functions with numerical masks	
Nights we used for KOIs	**110**	**5**

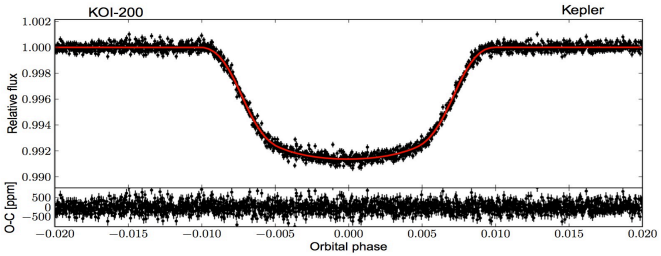
From SOPHIE to HARPS-N

1. Explore KOIs with detection hint or upper limit with SOPHIE (lower-mass planets)

Giant KOIs, close-in and with long periods

KOI-200b: a low-density, giant planet



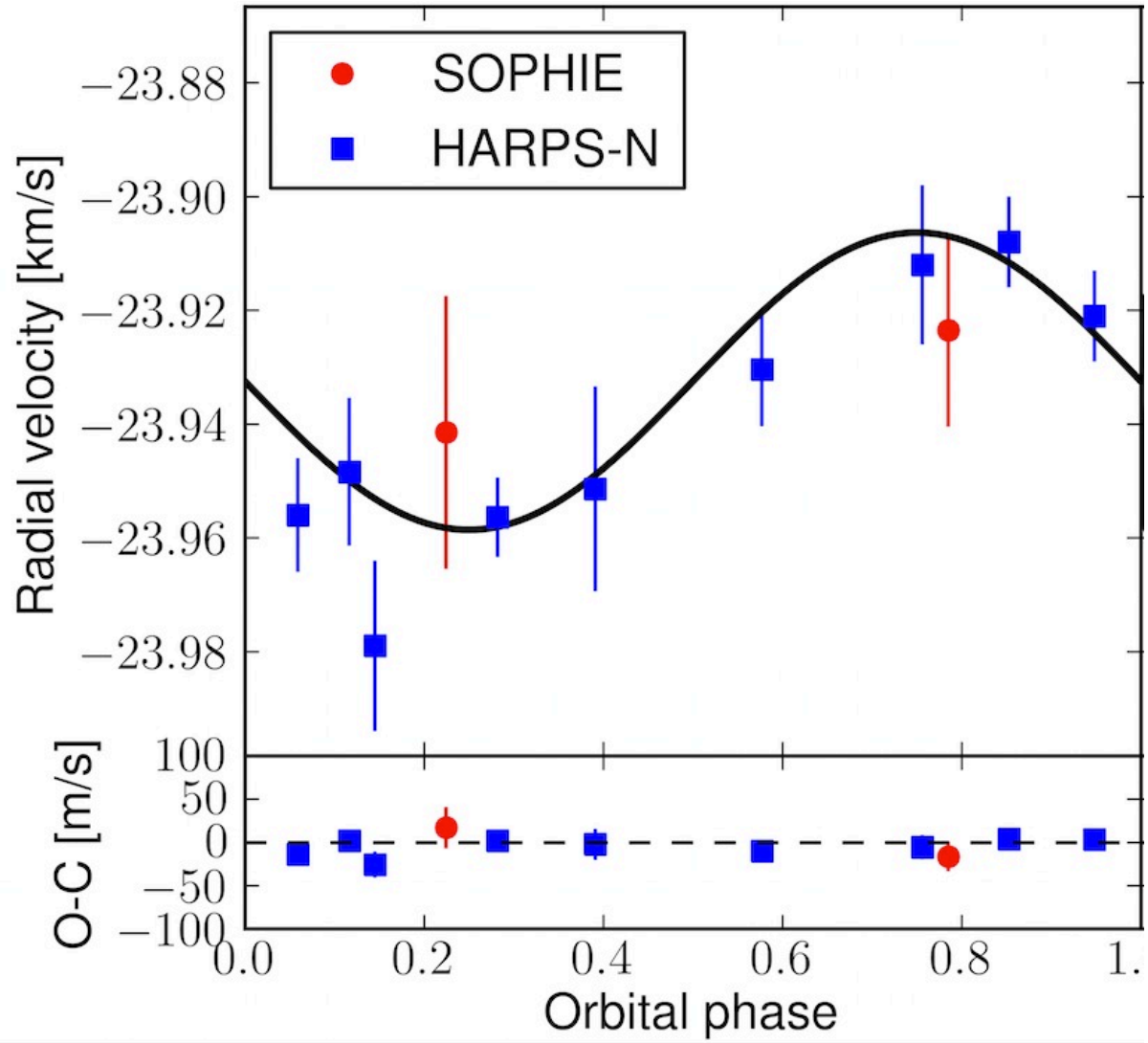


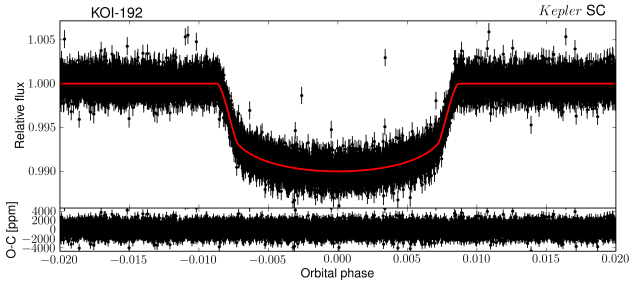
P = 7.34 d
d = 0.75%
K_{mag} = 14.41

K = 58 ± 7 m/s
m_p = 0.63 ± 0.11 M_{Jup}
r_p = 0.96 ± 0.02 R_{Jup}

Hébrard et al. (2013)
Bonomo et al. (2015)

KOI-192b: a warm Saturn





P = 10.29 d
d = 0.81%
K_{mag} = 14.22

K = 30 ± 9 m/s
m_p = 0.29 ± 0.09 M_{Jup}
r_p = 1.23 ± 0.21 R_{Jup}

Hébrard et al. (2014)

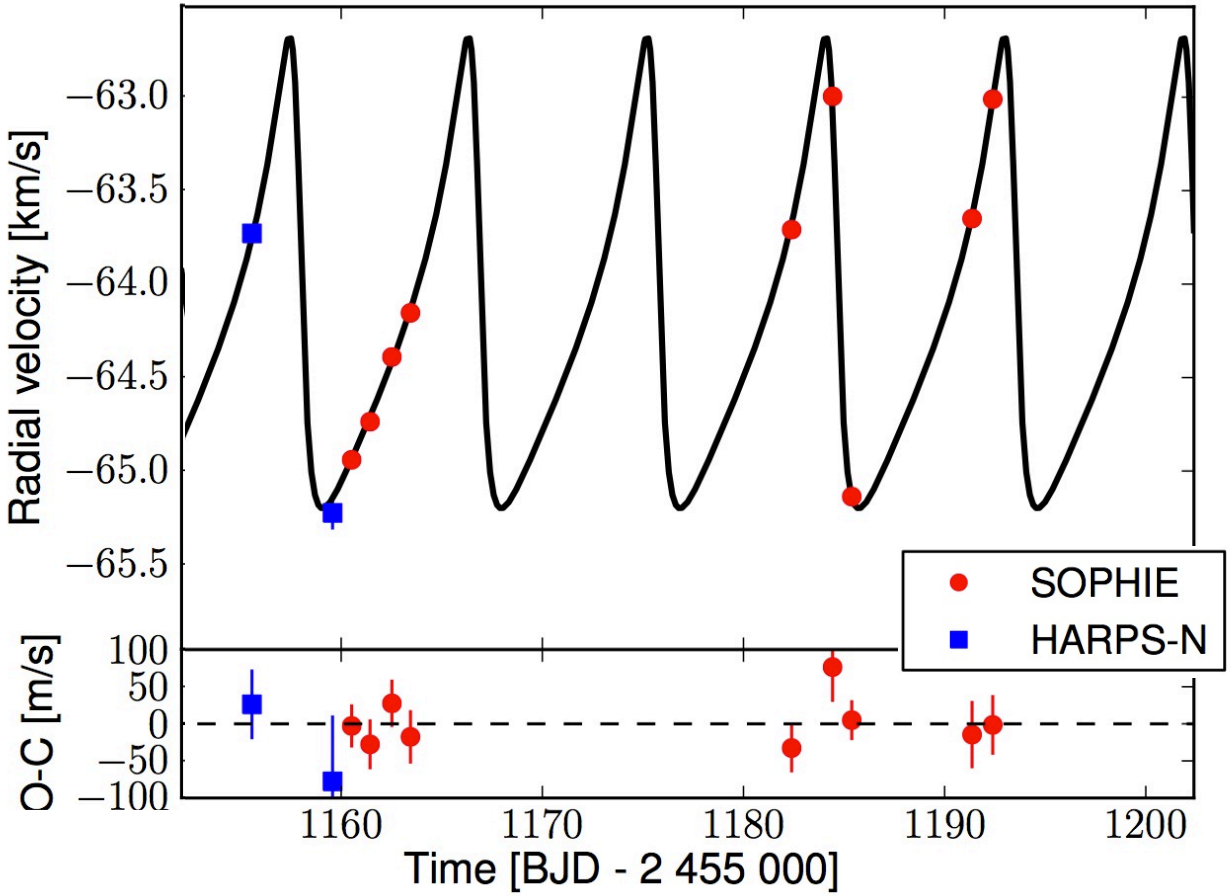
From SOPHIE to HARPS-N

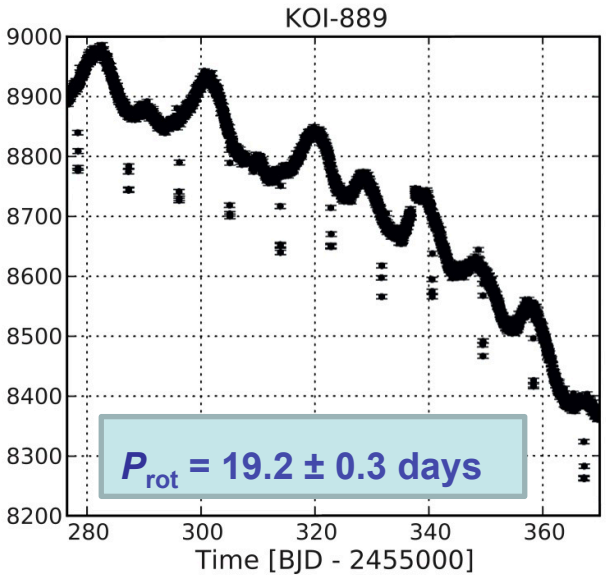
2. Probe giant, close-in KOIs toward fainter targets than with SOPHIE

P < 10d; d > 0.4%

K_{mag} = [14.7 – 15.3]

KOI-889b: a massive, eccentric planet





P = 8.88 d

d = 1.25%

K_{mag} = 15.26

K = 1288 ± 24 m/s

m_p = 9.9 ± 0.5 M_{Jup}

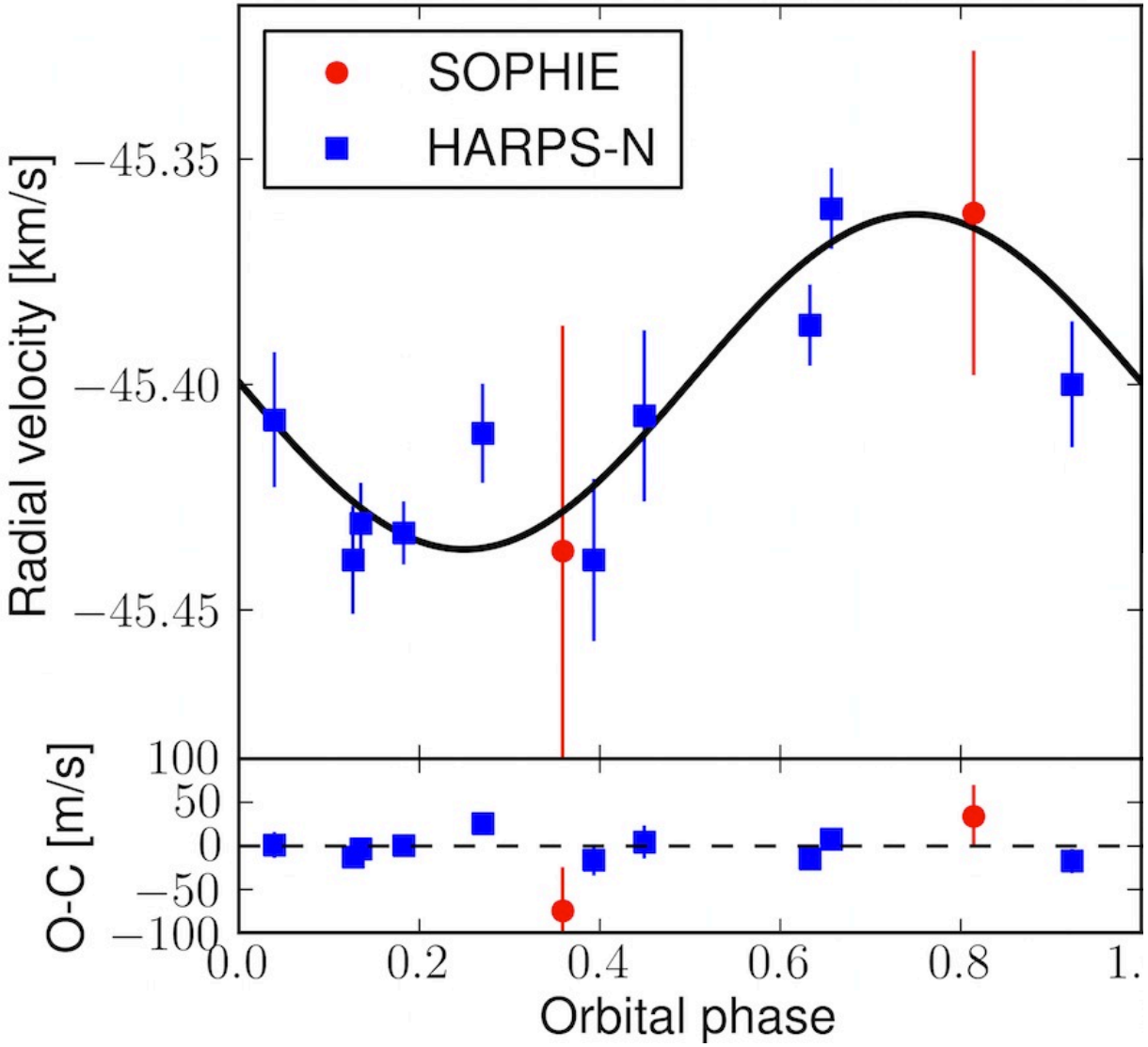
r_p = 1.03 ± 0.06 R_{Jup}

e = 0.57 ± 0.01

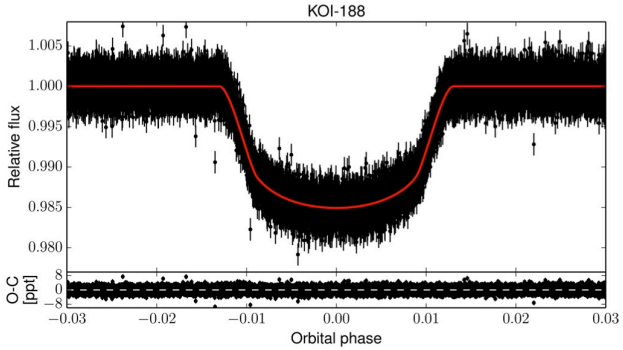
One of the rare Darwin-stable systems

Hébrard et al. (2013); Bonomo et al. (2015); Damiani et al. (2015)

KOI-188b: a hot Saturn



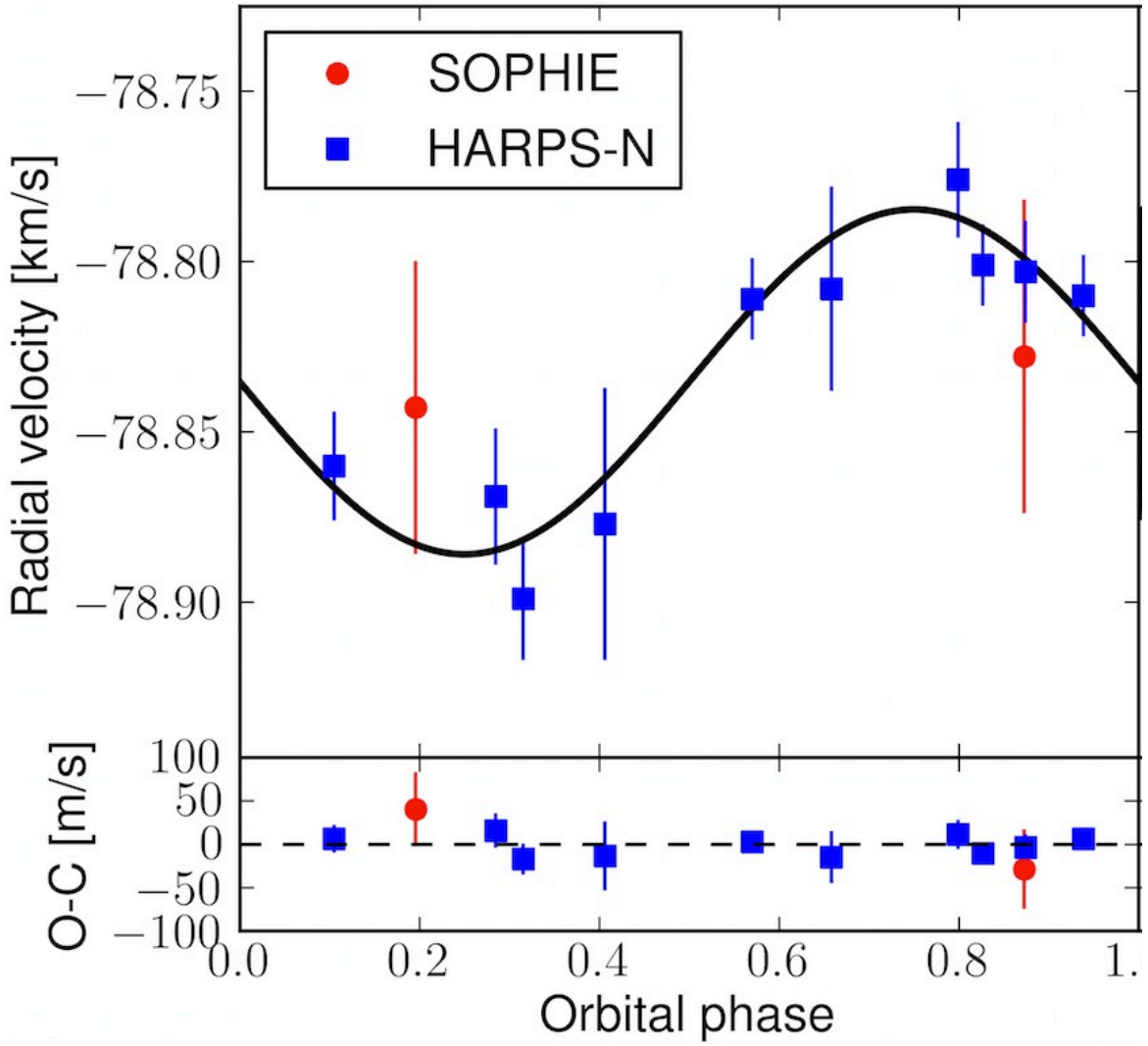
Hébrard et al. (2014)



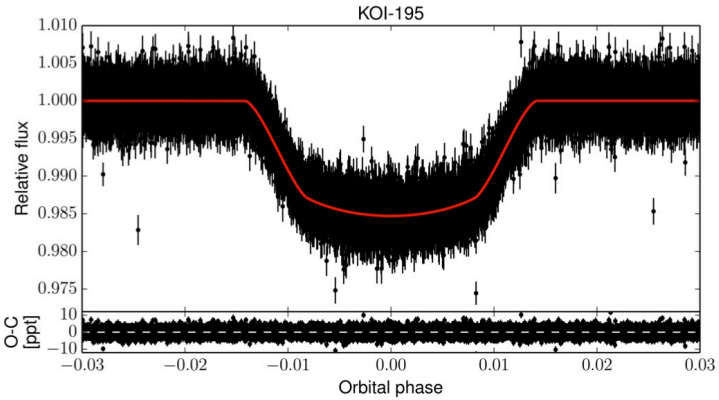
P = 3.79 d
d = 1.14%
K_{mag} = 14.74

K = 34 ± 10 m/s
m_p = 0.25 ± 0.08 M_{Jup}
r_p = 0.98 ± 0.02 R_{Jup}

KOI-195b: a hot Saturn



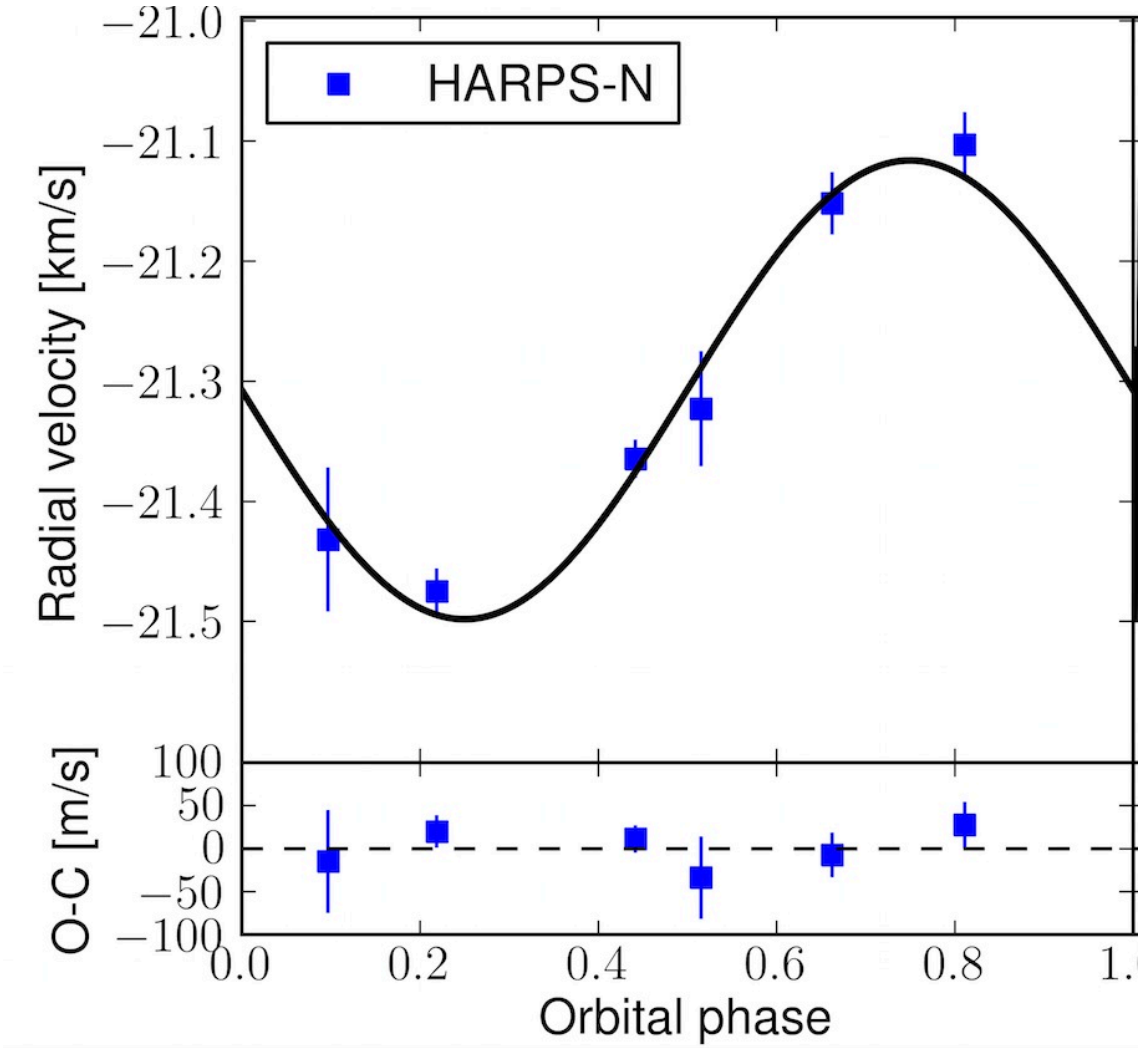
Hébrard et al. (2014)

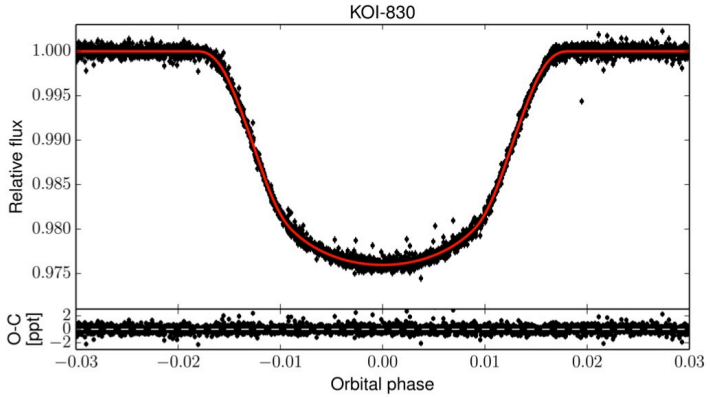


P = 3.22 d
d = 1.34%
K_{mag} = 14.84

K = 50 ± 10 m/s
m_p = 0.34 ± 0.08 M_{Jup}
r_p = 1.09 ± 0.03 R_{Jup}

KOI-830b: a hot Jupiter





P = 3.53 d
d = 1.76%
K_{mag} = 15.22

K = 185 ± 17 m/s
m_p = 1.30 ± 0.14 M_{Jup}
r_p = 1.09 ± 0.11 R_{Jup}

Hébrard et al. (2014)

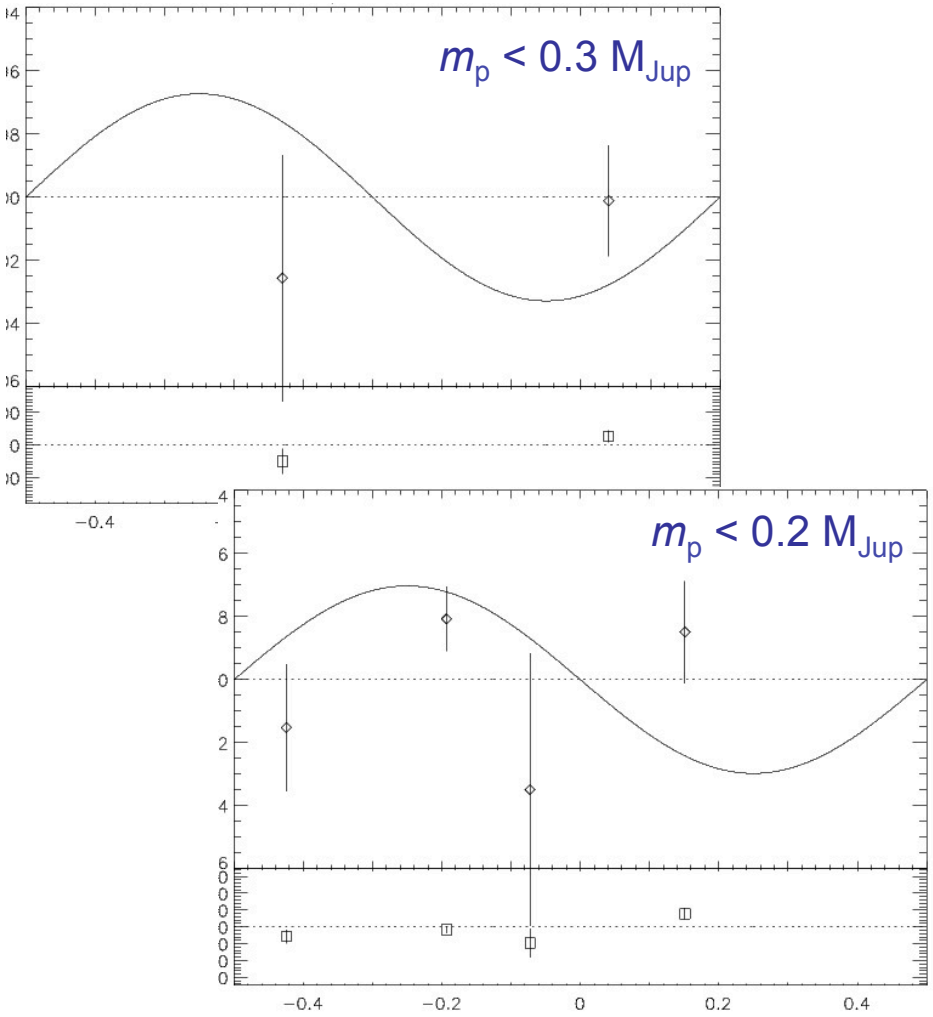
From SOPHIE to HARPS-N

3. Explore KOIs corresponding to smaller-radius planets

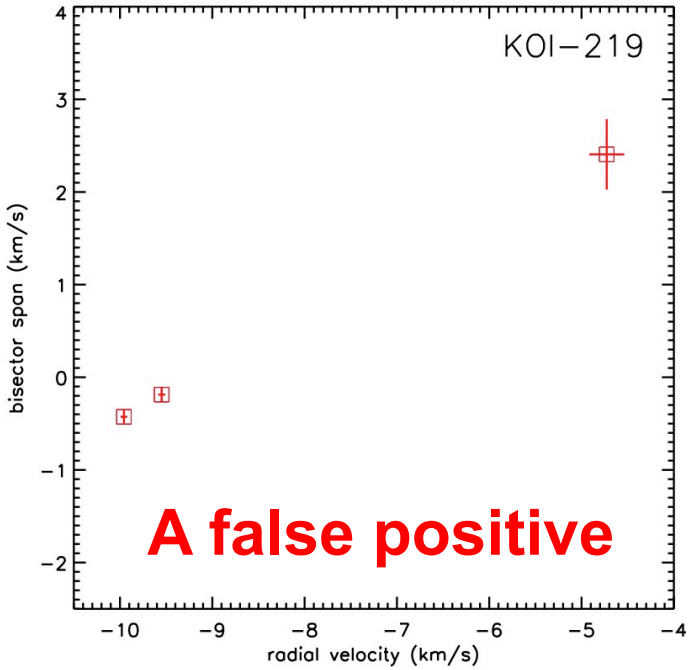
d = [0.2 – 0.4]%

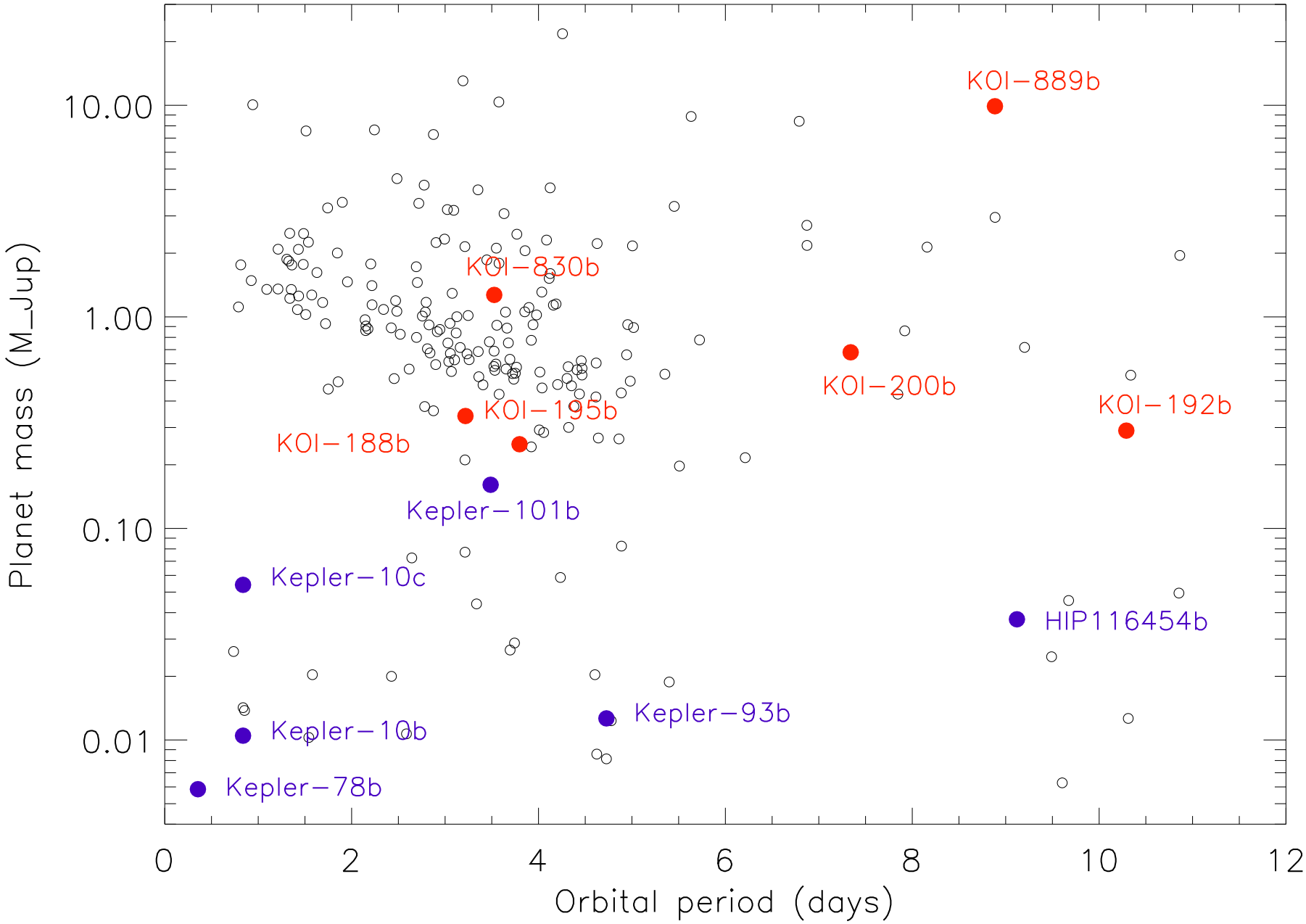
P < 10d; K_{mag} < 14.7

Small-radius KOIs



Mainly KOIs with no detected variations





Known exoplanets with measured mass and radius (circles). Among the 12 known transiting planets characterized with HARPS-N (filled circles), 6 are from the present program (red circles).

Conclusions

- Nice complementarity between SOPHIE and HARPS-N, two spectrographs with different sensitivities, precisions, and accessibilities.
- 6 new validated, characterized transiting planets (in 5 nights on HARPS-N).
- Extending the ranges in magnitude (K_{mag}), mass (m_p), and radius (r_p).
- Identification of additional likely planets.
- Identification of some false positives.
- **Extra HARPS-N observations are mandatory to provide statistics!**