

Detecting Low-Mass Planetary Systems with SOPHIE: Entering the SOPHIE-red Era

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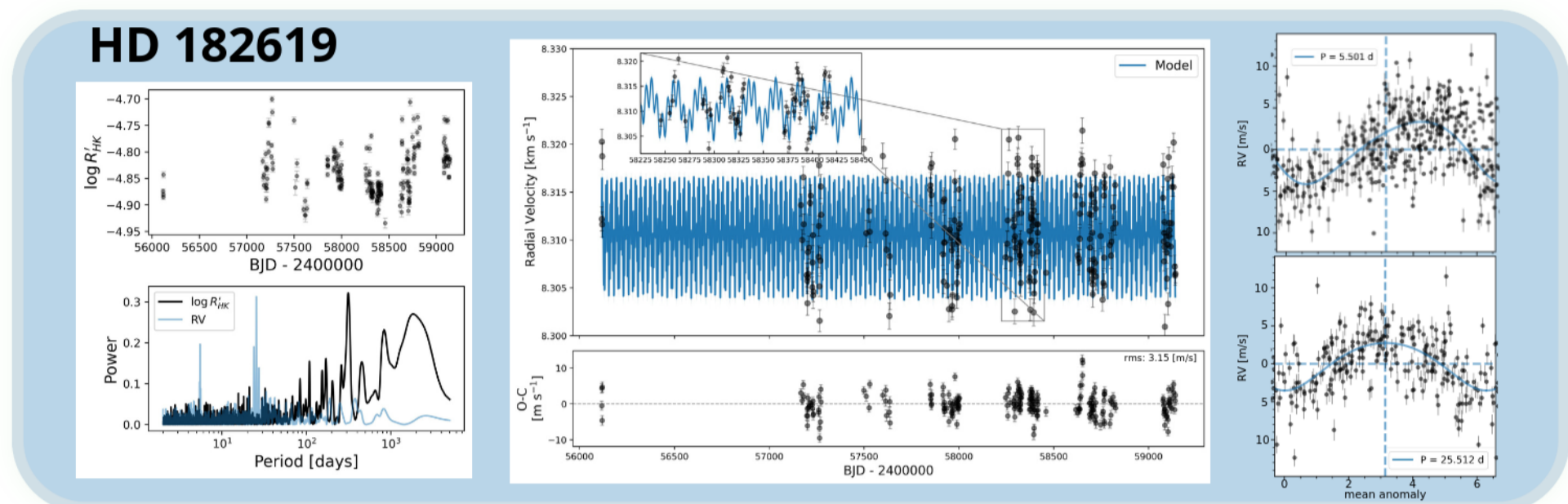
Installed on the 1.93-m telescope at Observatoire de Haute-Provence since 2006, **SOPHIE** is one of the few high-resolution spectrographs providing more than two decades of radial-velocity monitoring. Current high-precision programmes achieve $1\text{--}2\text{ m s}^{-1}$ precision on bright FGKM stars, enabling the detection of diverse planetary systems, but this performance degrades for fainter, cooler stars, limiting the detection of low-mass planets around late-K and M dwarfs. Yet, future atmospheric characterisation facilities (ELT/ANDES, ELT/PCS, HWO, LIFE) will rely on a large sample of such systems. To overcome this limitation, the **SOPHIE-red camera** extends the spectral range into the far-red and near-infrared, increasing both stellar flux and radial-velocity information for cool stars.

From G-type stars ...

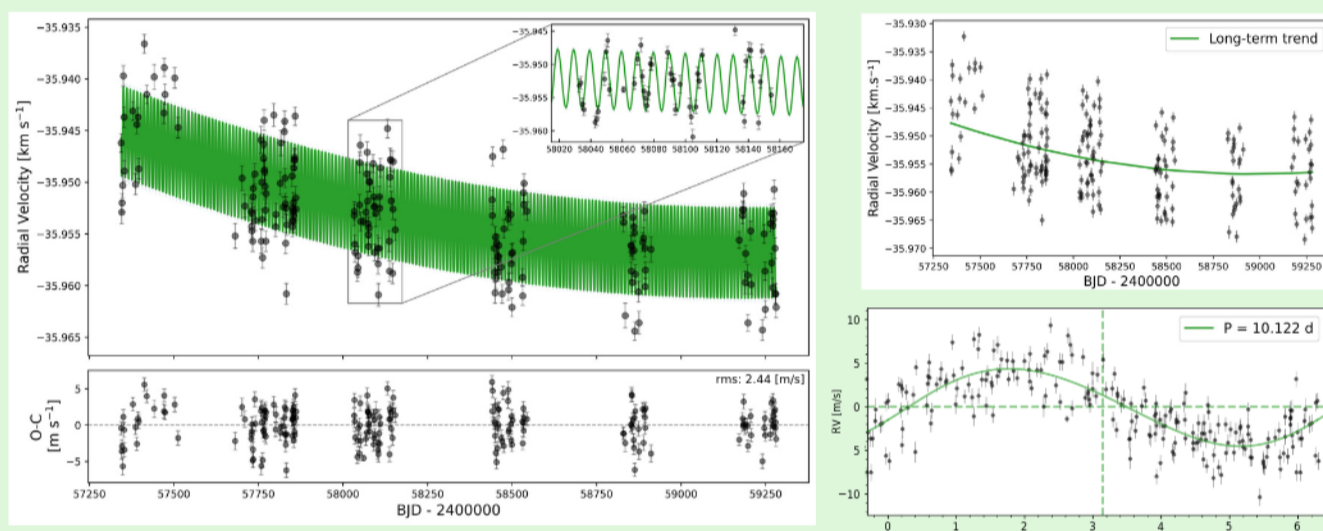
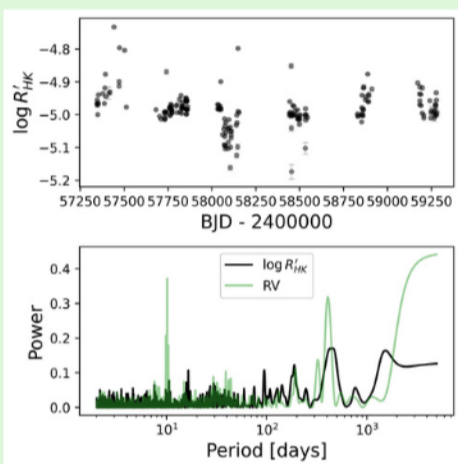
Detecting low-mass planets around bright G dwarf stars

- Compact multi-planet system of two short-period sub-Neptunes

Sp. Type	V [mag]	B-V [mag]	d [mag]	M* [Msun]	v sin i [km/s]	<log R'HK>
G5V	7.81	0.718	32.73	0.87	3	-4.835
P [d]	K [m/s]	Tp [BJD-2400000]	e	ω [rad]	a [AU]	Mp sin i [Mjup]
5.501 ± 0.001	3.09 ± 0.32	57631.07 ± 9.78	0.09 ± 0.09	2.92 ± 1.58	0.0582 ± 0.0002	7.69 ± 0.78
25.514 ± 0.150	3.58 ± 0.32	57649.00 ± 10.79	0.13 ± 0.09	2.49 ± 0.70	0.1619 ± 0.0006	14.80 ± 1.25



HD 67228



- Warm Neptune
- Long-term RV trend, possibly caused by an outer companion with no counterpart in stellar activity indicators, currently under investigation

Sp. Type	V [mag]	B-V [mag]	d [mag]	M* [Msun]	v sin i [km/s]	<log R'HK>
G0V	5.3	0.642	23.82	1.3	4.5	-4.979
P [d]	K [m/s]	Tp [BJD-2400000]	e	ω [rad]	a [AU]	Mp sin i [Mjup]
10.122 ± 0.001	4.36 ± 0.22	58315.00 ± 2.65	0.06 ± 0.04	4.20 ± 1.45	0.1000 ± 0.0013	17.51 ± 1.00

→ Both systems are detected and characterised exclusively through SOPHIE radial velocities. No convincing transit signal detected from available TESS and CHEOPS photometry.

Extending RVs to Cooler Stars with SOPHIE-red

...To M-type stars

Rather than being limited by instrumental stability, late-K and M dwarf RVs are increasingly photon-noise limited. Extending the wavelength coverage from the visible domain up to $\sim 900\text{ nm}$ with the new **SOPHIE-red** camera increases the SNR on these fainter targets and requires corresponding adaptations of the **Data Reduction Software**.



SPECTRAL EXTRACTION

Optimisation of extraction procedures for the new detector geometry and closely packed spectral orders.

Keywords: instrumental systematics · order crowding

WAVELENGTH CALIBRATION

Development of a dedicated calibration strategy for SOPHIE-red inspired by Hobson et al. (2021) and Cersullo et al. (2019).

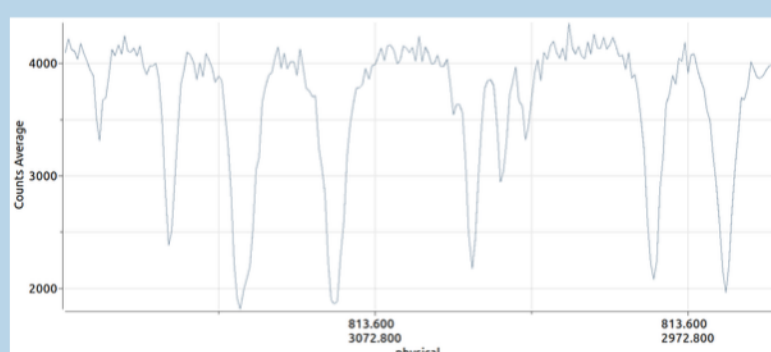
Keywords: Fabry-Pérot calibration · hollow-cathode lamp limitations · wavelength-solution stability



TELLURIC CORRECTION

Correction of atmospheric absorption features in the far-red domain to mitigate RV systematics.

Tellurics on order 47



Keywords: PCA/wPCA methods · residual mitigation · SPIRou/NIRPS-inspired approaches

