MINERVA-Australis is measuring the **masses** and **orbital obliquities** of **planets** discovered by ***TESS***.

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Introduction

MINERVA-Australis is the **only** southern hemisphere facility **fully dedicated** to the radial velocity (RV) follow-up of *TESS* candidate planets orbiting **bright** (V≤10) stars [1]. It is an array of **five** 0.7m telescopes located at the University of Southern Queensland's Mt Kent Observatory in Australia.

Each telescope feeds light through a fiber to a high-resolution (R~80,000) spectrograph. MINERVA-Australis is delivering RV precision of **better than 3m/s** and improvements to the spectrograph's thermal stability are expected to result in **~1m/s precision** in the near future.

Objectives

MINERVA-Australis primary objectives are:

1. Confirm *TESS* planet candidates. Only **21** out of **842** planet candidates have been confirmed [2].
2. Measure their **masses** & **eccentricities**. In particular for sub-Jovians, warm-Jupiters, & multi-planet systems.
3. Determine planet **bulk compositions** from MINERVA-Australis mass measurements & radii from *TESS*. This will distinguish compositions of sub-Neptunes.
4. Probe **planet formation** & **migration** through **spin-orbit angle** (**λ**) measurements via the Rossiter-McLaughlin effect [3,4,5]. Few measurements exist for **long-period planets** and **multi-planet systems**.
5. Search for **long-period planets** (such as Jupiter & Saturn analogs) by long-term RV monitoring of *TESS* targets to establish the **frequency of Solar System analogs** [6].

Results & Conclusions

MINERVA-Australis is perfectly suited for RV follow-up of *TESS* planet candidates. This facility has already helped to **confirm three *TESS* planetary systems** around HD 1397, DS Tuc, & HR 858 [7,8,9]. We are actively following-up several dozen candidate planets to confirm their planetary nature, and to measure their masses and orbital obliquities.

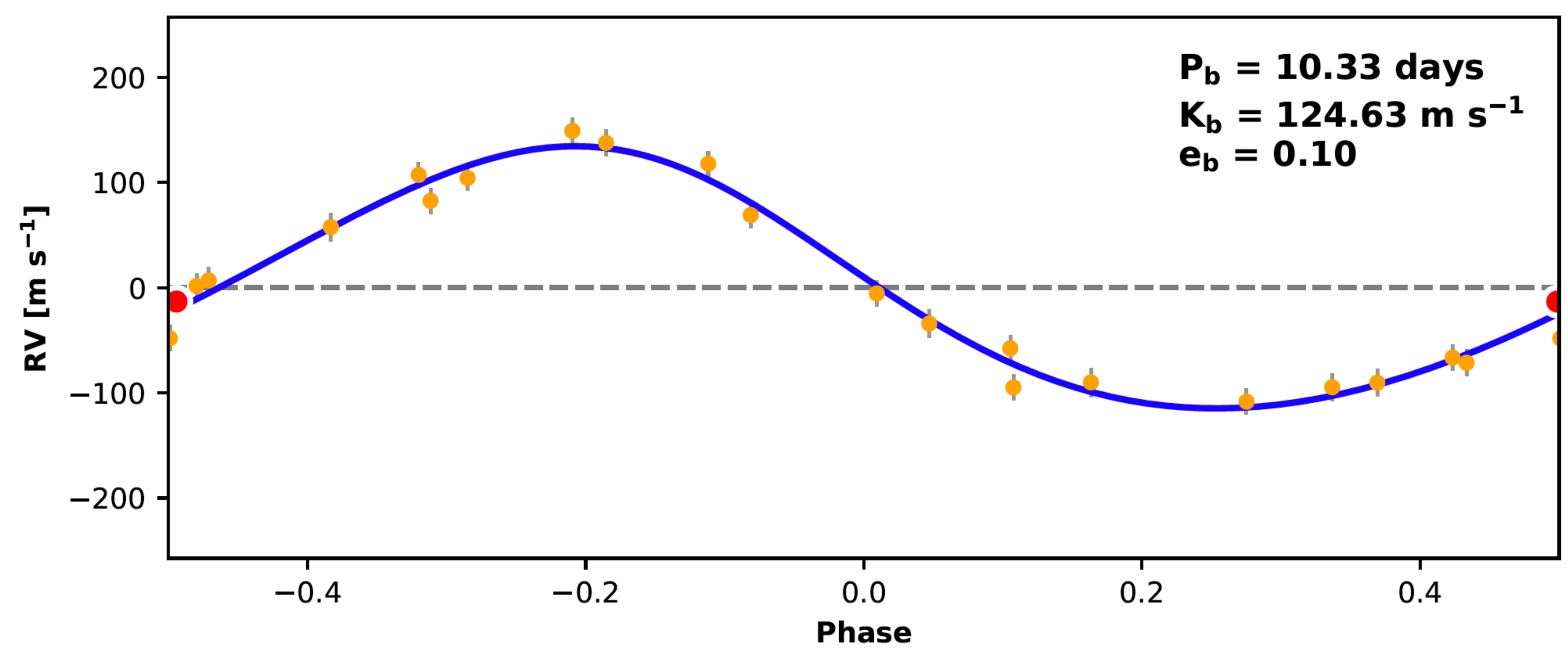

Fig. 1: Radial velocities from MINERVA-Australis confirming a *TESS* warm-Jupiter on a slightly eccentric orbit.

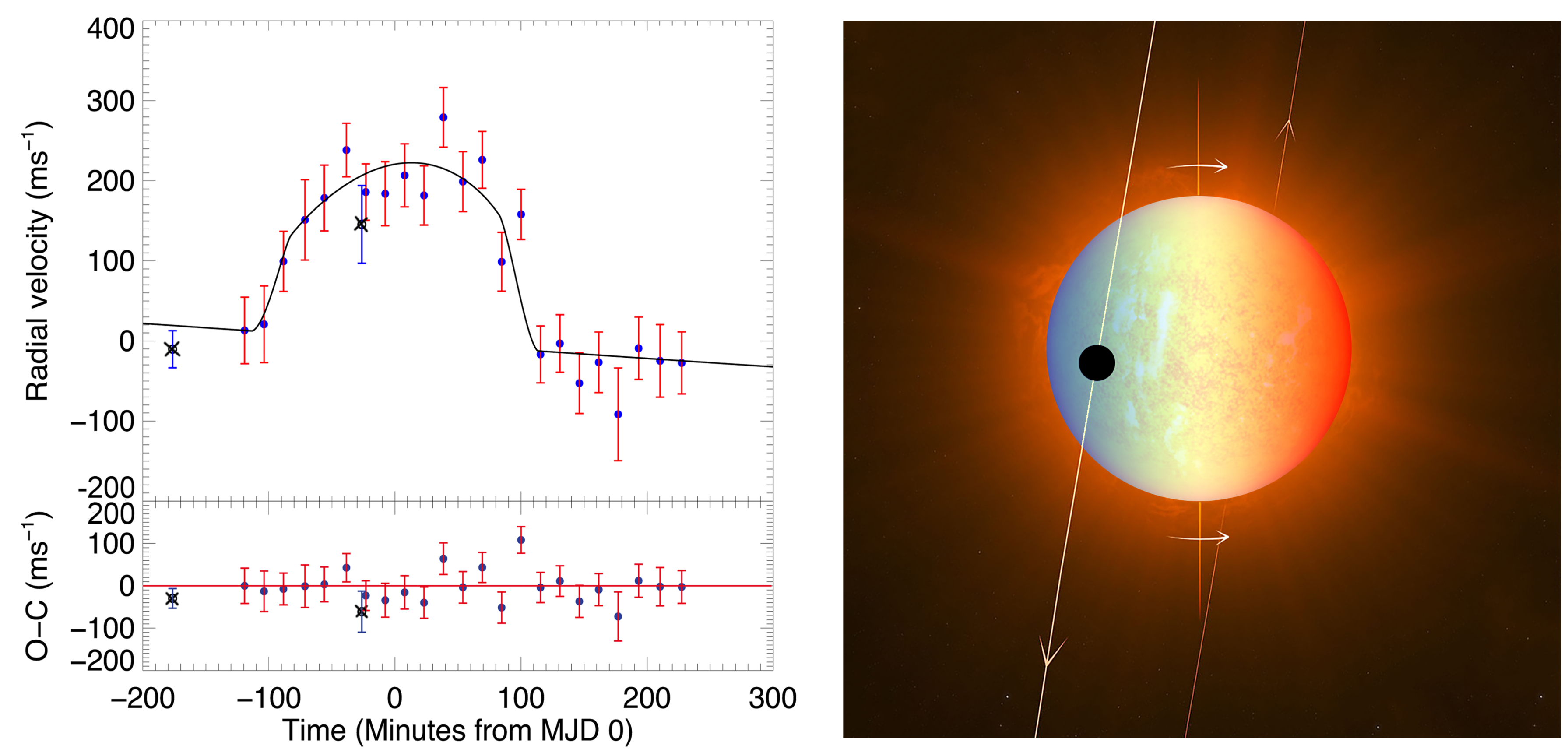

Fig. 2: On the left, radial velocity observations from the Anglo-Australian Telescope showing the Rossiter-McLaughlin effect for WASP-79b, indicating that the planet is in a polar orbit [10]. On the right, an artist impression of the polar orbit for this planet with the star shaded blue and red to indicated the side approaching (blue) and receding (red).

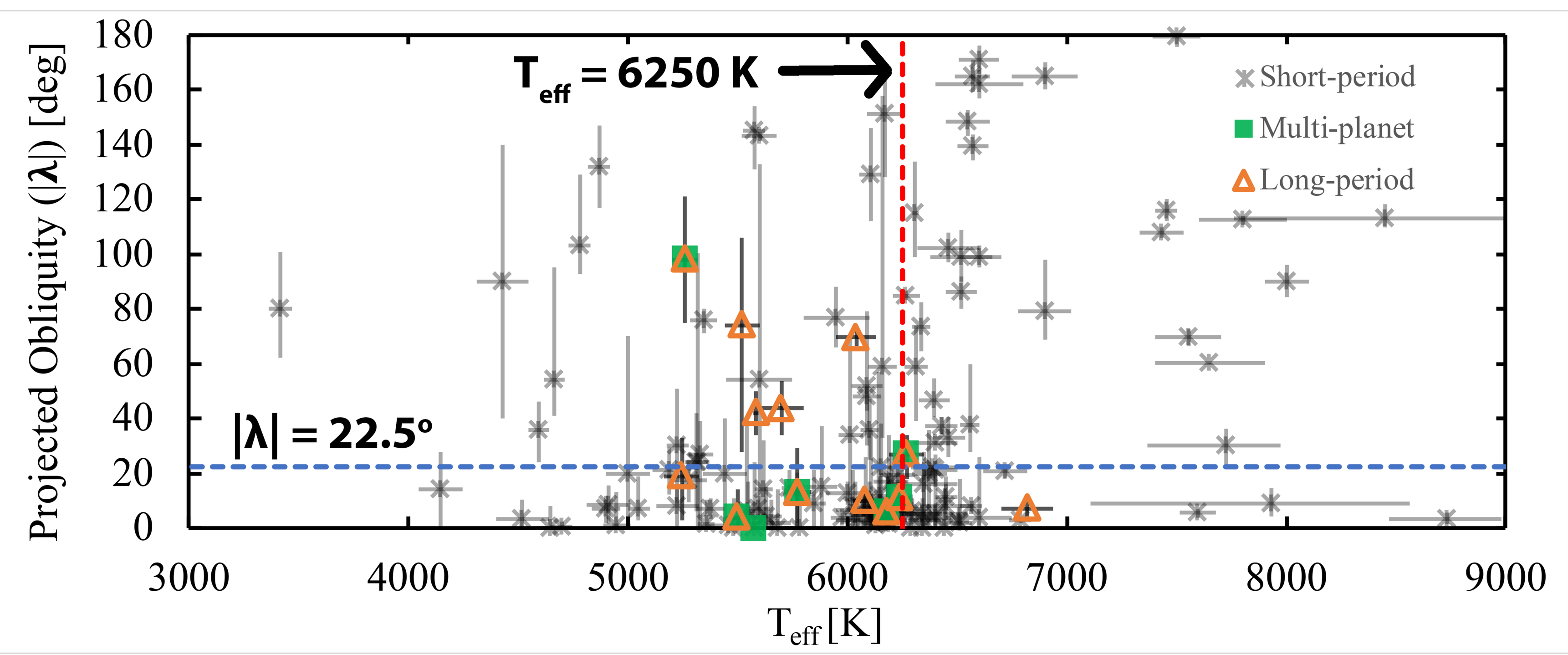

Fig. 3: Projected spin-orbit alignments of all the measured exoplanetary systems as a function of their host star's effective temperature. Few measurements exist for multi-planet systems and long-period planets. Early trends observed between stellar effective temperature and spin-orbit misalignment [11] are no longer apparent in the larger sample.

References

[1] **Addison, B. C.**, et al. 2019, arXiv:1901.11231. [2] https://exoplanetarchive.ipac.caltech.edu/ (NASA Exoplanet Archive). [3] Rossiter, R. A. 1924, ApJ, 60, 15. [4] McLaughlin, D.B. 1924, ApJ, 60, 22. [5] Winn, Joshua N. et al., 2005, ApJ, 631, 1215. [6] Wittenmyer, R. A., et al. 2017, AJ, 153, 167. [7] Nielsen, L. D., et al. 2019, A&A, 623, 100. [8] Newton, E. R., et al. 2019, arXiv:1906.10703. [9] Vanderburg, A., et al. 2019, arXiv:1905.05193. [10] **Addison, B. C.**, et al. 2013, ApJL, 774, 9. [11] Albrecht, S., et al. 2012b, ApJ, 757, 18.

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