SF2A 2026
A. Siebert, K. Baillié, M. Béthermin, F. Cantalloube, S. Guerlet, E. Josselin, J. Richard (eds)

AN ULTRA-CLOSE NON-TRANSITING HOT NEPTUNE AROUND A SOLAR-TYPE STAR OBSERVED BY KEPLER?

S. N. Breton[1], A. Dyrek[2], C. Gourvès[3], C. Allende Prieto[4,5], A. Bonfanti[6], H. J. Deeg[4,5], R. A García[3], E. Pallé[4,5], F. Pérez Hernández[4,5], O. Benomar[6,7,9], L. Borg[3], I. Carleo[10], A. F. Lanza[1], K. Masuda[11], S. Mathis[3], S. Mathur[4,5], D. B. Palakkatharappil[3], A. R. G. Santos[3] and F. Selsis[12]

Abstract. Close-in low-mass planets experience dramatic atmospheric escape under the action of stellar irradiation, resulting in the existence of a depleted region in the mass-radius diagram referred as the Neptune desert, populated only by a few planetary objects. Combining *Kepler*, TESS and HARPS-N observations, we present evidence that KIC 9139163, a well characterised solar-type star, hosts the first non-transiting exoplanet detected in the Neptunian desert. We carry out a first attempt at characterising the properties of the candidate planet. In particular, we argue that the phase difference observed in the signal between the *Kepler* and TESS phase curves can be interpreted as a signature of decadal atmospheric variability. If definitely confirmed, this candidate would represent a privileged target to study atmospheric dynamics of hot Neptunes.

Keywords: exoplanets, solar-type stars, photometry, spectroscopy

1 Introduction

Close-in non transiting planets can be detected in photometry thanks to the signal of their phase curve, which combines reflection, thermal emission, stellar tidal deformation, and Doppler boosting (Shporer 2017; Lillo-Box & Balsalobre-Ruza 2026). Following this approach, Gourvès et al. (2025) characterised 88 new non-transiting candidate planets in the *Kepler* survey. Radial velocity (RV) follow-up with HARPS-N and detailed phase curve analysis (Breton, Dyrek et al. 2026) revealed that the brightest star in the sample, KIC 9139163, may host an ultra-close hot Neptune.

2 Characterisation of the system

2.1 Observations with HARPS-N

An observation campaign for KIC 9139163 was performed with HARPS-N from March to August 2022. Fifty-nine spectra were acquired on short exposures (less than 5 min). The spectra were reduced and analysed following the method of Bonfanti et al. (2023, 2025). A statistically significant detection was obtained in the RV time series, which enabled the characterisation of the time of superior conjunction. The corresponding $M_p \sin i$ value we obtained was 7.28 ± 1.38 $M_\oplus$.

[1] INAF - Osservatorio Astrofisico di Catania, Via S. Sofia, 78, 95123 Catania, Italy
[2] Space Telescope Science Institute, Baltimore, MD, USA
[3] Université Paris-Saclay, Université Paris Cité, CEA, CNRS, AIM, 91191 Gif-sur-Yvette, France
[4] Instituto de Astrofísica de Canarias (IAC), Vía Láctea S/N, La Laguna 38200, Tenerife, Spain
[5] Departamento de Astrofísica, Universidad de la Laguna, La Laguna 38200, Tenerife, Spain
[6] Space Research Institute, Austrian Academy of Sciences, Schmiedlstrasse 6, 8042 Graz, Austria
[7] Department of Astronomical Science, School of Physical Sciences, SOKENDAI, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
[8] Solar Science Observatory, National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
[9] New York University Abu Dhabi, Center for Space Science, PO Box 129188, Abu Dhabi, UAE
[10] INAF - Osservatorio Astrofisico di Torino, Via Osservatorio 20, 10025 Pino Torinese, Italy
[11] Department of Earth and Space Science, Osaka University, Osaka 560-0043, Japan
[12] Laboratoire d'astrophysique de Bordeaux, University of Bordeaux, CNRS, Pessac, France

© Société Française d'Astronomie et d'Astrophysique (SF2A) 2026

2.2 Characterisation of the photometric phase curve

The phase curves were analysed with a 1D model of emission/reflection accounting for the longitudinal offsets introduced by clouds and heat redistribution. Best-fit models were found to have moderate-to-high geometrical albedos (>0.5) and low-to-moderate heat redistribution. The phase of the signal evolved between *Kepler* (from 2009 to 2013) and TESS (from 2018 to 2025) observations which is interpreted as a possible evidence for atmospheric variability at the decadal level. The candidate planet is located above the lower edge of the Neptune desert (see Fig. 1) and represents an extremely interesting candidate for future follow-ups. There are very few planets in this parameter range that possess photometric phase curves in the optical wavelengths.

3 Perspectives for the future

New HARPS-N and GIANO-B observations to confirm the planetary companion through the characterisation of the atmospheric composition will be carried out in the near future. In particular a director discretionary time (DDT) request to observe the system was recently accepted and a full night of observation in June 2026 was granted. Infrared spectroscopy may also play a crucial role to infer atmospheric composition. Indeed, if definitely confirmed, KIC 9139163 would become a valuable target for future JWST observations. Finally, the PLATO mission (Rauer et al. 2025) will be launched early 2027 and should allow us to assemble an extended sample of close-in non-transiting planets around bright stars from their phase modulations.

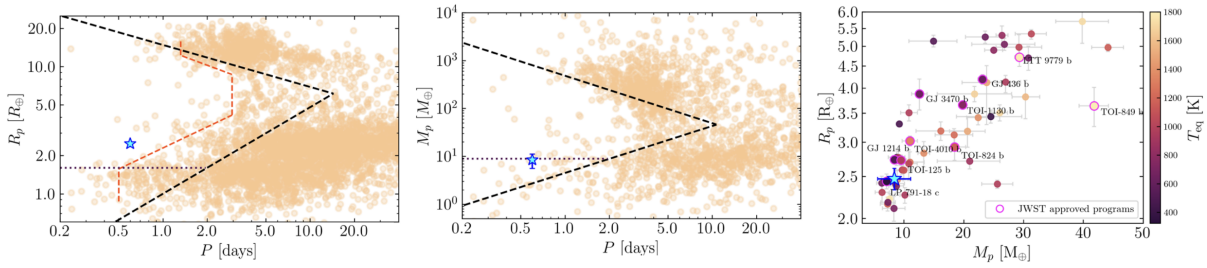


Fig. 1. Location of the KIC 9139163 system (*blue star*) in the radius versus orbital period (*left*), mass versus orbital period (*middle*), and radius-mass diagrams (*right*), respectively. The adopted values are the minimal mass inferred from the RV analysis and the radius derived from the modelling of the phase curve. Other known systems from the NASA exoplanet archive are represented as orange dots in the left and middle panels, systems observed by JWST are represented in the right panel. The dashed black lines show the boundaries of the Neptune desert from Mazeh et al. (2016), the horizontal dotted black lines show the updated lower limits from Deeg et al. (2023), the red lines are the boundaries following the prescription of Castro-González et al. (2024). Figure taken from Breton, Dyrek et al. (2026).

References

Bonfanti, A., Amateis, I., Gandolfi, D., et al. 2025, A&A, 693, A90
Bonfanti, A., Gandolfi, D., Egger, J. A., et al. 2023, A&A, 671, L8
Breton, S. N., Dyrek, A., Allende Prieto, C., et al. 2026, A&A, 712, A237
Castro-González, A., Bourrier, V., Lillo-Box, J., et al. 2024, A&A, 689, A250
Deeg, H. J., Georgieva, I. Y., Nowak, G., et al. 2023, A&A, 677, A12
Gourvès, C., Breton, S. N., Dyrek, A., et al. 2025, A&A, 699, A226
Lillo-Box, J. & Balsalobre-Ruza, O. 2026, arXiv e-prints, arXiv:2609.20355
Mazeh, T., Holczer, T., & Faigler, S. 2016, A&A, 589, A75
Rauer, H., Aerts, C., Cabrera, J., et al. 2025, Experimental Astronomy, 59, 26
Shporer, A. 2017, PASP, 129, 072001