Magnetic field and space environment of known exoplanet hosts: GJ 436 and HD 63433

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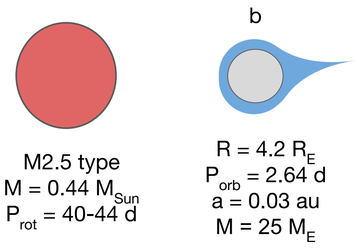
Paper I Bellotti et al. 2023, A&A, 676, A139

Paper II Bellotti et al. 2024, arxiv, in press at A&A

Context

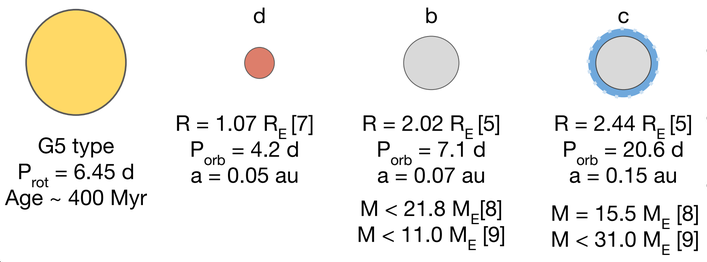
The space environment in which planets are embedded mainly depends on the host star and impacts the evolution of the planetary atmosphere. Planets orbiting close (< 0.1 au) to the host star experience energetic stellar irradiation (X-rays and extreme ultraviolet) that heats the upper regions of the atmosphere, resulting in hydrodynamic escape [1]. Furthermore, stellar particles from magnetised wind and coronal mass ejections can confine and strip planetary atmospheres away [2]. This work focuses on the characterisation of the magnetic field and environment of the exoplanet hosts GJ 436 (paper I) and HD 63433 (paper II).

GJ 436 system



- The planet's atmosphere is subject to hydrodynamic escape and forms a comet-like cloud of hydrogen atoms [3].
- The planetary orbit is nearly-polar, with an inclination of 72° [3]
- The flare distribution of GJ 436 reported by [4] showed a lack of energetic events, possibly due to star-planet interactions.

HD 63433 system



- Planet b does not show Lyα or He triplet absorption
- Planet c only exhibits Lyα absorption
- Planet d is a hot Earth-sized planet
- The planetary atmospheres have experienced different evolution paths [5,8,9]

References

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[2] Carolan et al. (2021), MNRAS, 500, 3382
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[4] Loyd et al. (2023), AJ, 165, 146
[5] Zhang et al. (2022), AJ, 163, 68
[6] Mann et al. (2020), AJ, 160, 179
[7] Capistrant et al. (2024), AJ, 167, 54
[8] Mallorquin et al. (2023), A&A, 671, A163
[9] Damasso et al. (2023), A&A, 672, A126
[10] Donati & Brown (1997), A&A, 326, 1135
[11] Vidotto et al. (2023), A&A, 678, A152

Acknowledgements

We acknowledge funding from the French National Research Agency (ANR) under contract number ANR-18-CE31-0019 (SPlaSH). S. B. acknowledges funding from the SCI-S department of the European Space Agency (ESA), under the Science Faculty Research fund E/0429-03.

Stellar Magnetic Field and Wind Simulation

We reconstructed the **large-scale geometry** of the magnetic field of GJ 436 and HD 63433 with Zeeman-Doppler imaging [ZDI;10], using optical spectropolarimetric observations collected with Narval@Pic du Midi (France).

- GJ 436: The large-scale topology is **dipolar**, **axisymmetric** with an average strength of **16 G**
- HD 63433: The large-scale topology is **complex** with an average strength of **24 G**

The radial magnetic field is extrapolated to the corona and used as a boundary condition to simulate the stellar wind. We performed data-driven 3D MHD simulations using the Alfvén Wave Solar Model (AWSoM) implemented in the numerical code BATS-R-US. Figure 1 shows both the magnetic field maps and the stellar wind models (see also [11, paper II]).

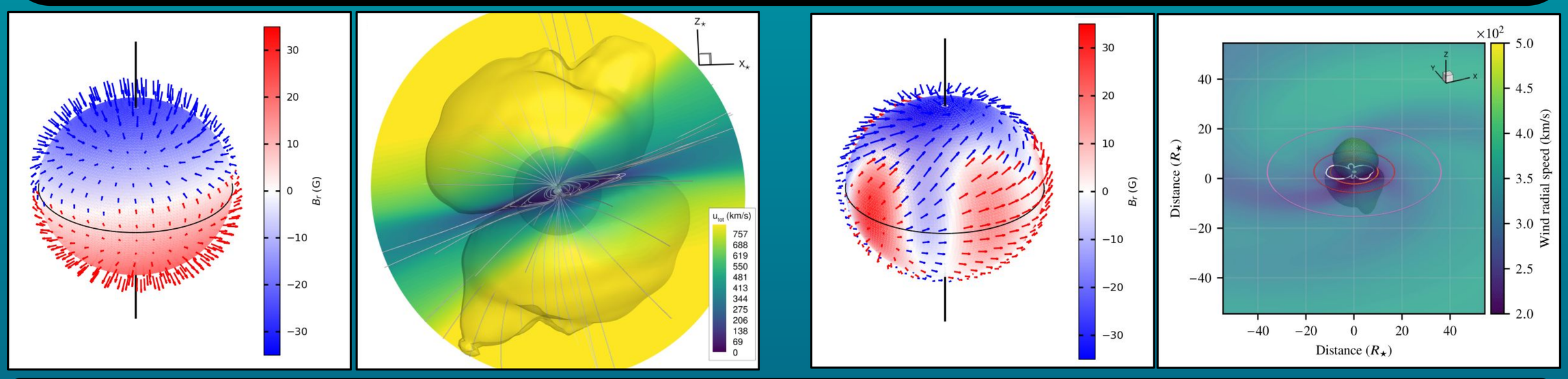

Fig. 1 – Two panels on the left: magnetic map of the radial field with positive and negative polarity and stellar wind model, where the color indicates the wind speed, the grey circle is the planetary orbit, the Alfvén surface has an irregular shape, and the grey streamlines are the magnetic field lines. Two panels on the right: same as left but for HD 63433 planetary system.

Results: Stellar Environment

- The stellar wind properties at the location of planet **GJ 436 b** are continuously changing because of the orbit is nearly-polar and crosses regions of open and closed magnetic field lines (see Fig. 2). The planetary orbit is sub-Alfvénic, meaning that it lies in the region of space where magnetic forces dominate over inertial forces, and thus it has a magnetic connectivity with the star. Two possible star-planet interactions scenarios are: i) magnetic reconnection between the stellar and the planetary magnetic field, and ii) perturbation of stellar magnetic field lines by the planetary motion.
- For **HD 63433 b** and **c**, the orbit is super-Alfvénic (Mach number > 1), so a bow shock between the stellar wind and a planetary magnetosphere (if present) can form. Instead, 10% of **HD 63433 d** orbit, the motion is sub-Alfvénic.

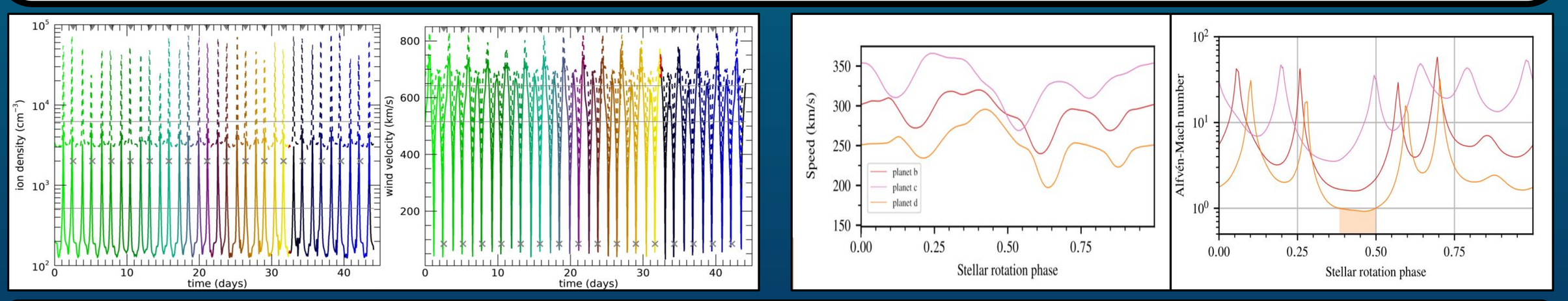

Fig. 2 – Two left panels: stellar wind environment at the GJ 436 b orbit for multiple orbits. Dashed and solid lines represent two stellar wind models, and the grey crosses indicate observational constraints. Two right panels: HD 63433 wind environment at the orbit of the three planets. The orange window in the right panel indicates when the orbit is sub-Alfvénic.