USING AURORAE TO CHARACTERIZE PROXIMA CENTAURI b.

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Introduction: The recently discovered exoplanet Proxima Centauri b, a small planet in the habitable zone of the star closest to the Sun, offers an unprecedented opportunity to study the habitability of exoplanets [1]. Unfortunately, Proxima Centauri b likely does not transit its star [2], and given its extremely close-in orbit (a = 0.0485 AU), directly imaging the planet is not yet possible with current coronagraphs [3,4]. In this work, we consider the possibility of using planetary auroral emission to characterize Proxima Centauri b [5]. Auroral emission from exoplanets is typically too faint to be observed, even for hot Jupiters [e.g., 6]. However, multiple factors contribute to make aurorae on Proxima Centauri b potentially observable from Earth. The host star has a magnetic field ~600 times stronger than that of the Sun [7], and the planet is ~20 times closer to its star than Earth is to the Sun, resulting in orders of magnitude higher stellar particle flux incident on Proxima Centauri b when compared to Earth. Moreover, the redder spectrum of Proxima Centauri compared to the Sun enhances the contrast of planetary auroral features in the optical and UV portions of the spectrum. Finally, the relatively high orbital velocity (~50 km/s) of the planet will Doppler-shift any auroral emission by as much as 1Å over the course of its orbit, naturally de-convolving it from both stellar and telluric emission.

Signal Strength: For different assumptions of the planetary and stellar properties, we use the results of a 3D magnetohydrodynamical (MHD) model [8] to calculate the expected auroral emission strength of Proxima Centauri b during steady-state, substorm, and coronal mass ejection (CME) conditions for the oxygen (OI) green auroral line at 5577Å. Assuming Proxima Centauri b is similar in composition to Earth, we find that the auroral output at 5577Å is on the order of 0.1TW during steady-state stellar wind, or about 100 times stronger than on Earth. During vigorous flares and CME events, auroral output of 1–10TW (1,000–10,000 stronger than on Earth) is possible.

Detectability: The estimates listed above correspond to a planet/star contrast at the OI line ranging from 10^{-7} to 10^{-4}. We examine the possibility of detecting this signal with current and planned telescopes, and find that detecting a 0.1TW steady-state 5577Å aurora (depicted in the Figure) is likely infeasible. However, observations with future large-aperture, space-based coronagraphic telescopes or ground-based extremely large telescopes (ELTs) equipped with coronagraphs could detect 1TW aurorae with exposure times of ~1 day at high spectral resolution. Given the high rate at which Proxima Centauri flares [9], such aurorae may be common on Proxima Centauri b, depending on its composition.

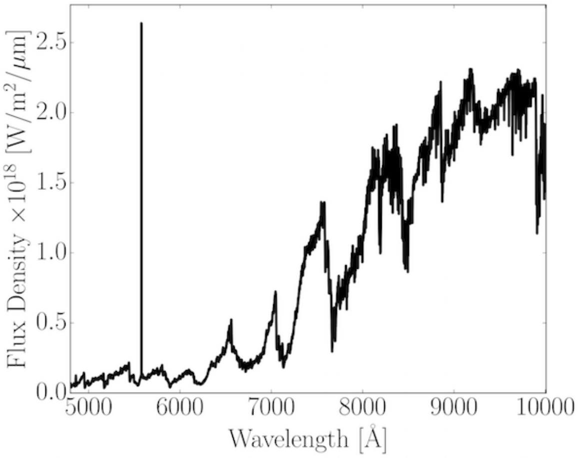

***Figure:** Predicted reflectance spectrum for Proxima Centauri b assuming an Earth-like atmosphere and 0.1TW OI auroral emission.*

HARPS Search: We searched for the OI auroral signal from Proxima Centauri b in the high resolution HARPS spectra used in the discovery [1], but find no signal, consistent with our detectability calculations above. Using the methods we discuss here, the detection of auroral emission from Proxima Centauri b could allow one to (1) confirm the existence of the planet, (2) break the radial velocity (RV) mass/inclination degeneracy and verify the planet's terrestrial nature, (3) determine the planet's orbital eccentricity, (4) determine whether a planetary magnetic field exists and place limits on its strength, and (5) infer the bulk atmospheric composition of the planet, thereby helping constrain its habitability.

References: [1] Anglada-Escudé, G. et al. (2016) *Nature*, 536, 437. [2] Kipping, D. et al. (2016) *arXiv: 1609:08718*. [3] Macintosh, B. et al. (2014) *PNAS*, 111, 12661. [4] Beuzit, J.-L. et al. (2008) *GAIA VI*, 701418. [5] Luger, R. et al. (2016) *arXiv:1609.09075*. [6] France, K. et al. (2010) *ApJ*, 712, 1277. [7] Reiners, A. and Basri, G. (2008) *A&A*, 489, L45. [8] Wang, C. (2014) *JGRSP*, 119, 6199. [9] Davenport, J. et al. (2016) *arXiv:1608.06672*.