

**Effects of Space Weather on Habitability of Proxima b.** V. S. Airapetian<sup>1</sup>, <sup>1</sup>NASA/GSFC, Greenbelt, MD, US (vladimir.airapetian@nasa.gov).

### Introduction:

Discovery of thousands of exoplanets around cool main-sequence stars has dramatically changed the landscape of exoplanetary science. Large fraction of exoplanets are located close to their host stars. The inner edges of habitable zone for M dwarfs range between 0.05 to 0.15 AU. Thus, atmospheres of terrestrial exoplanets in the habitable zones (HZ) around M stars are subject to extreme *X-ray* and EUV (*XUV*) fluxes from their host stars that can initiate atmospheric erosion. Here we discuss the impact of space weather rate due to the combined effect of XUV irradiation and dynamic pressure from the wind/CMEs from the host star, Proxima Cen, on the recently discovered Earth-like exoplanet, Proxima b, located within the HZ [1].

### XUV Driven Mass Loss From Proxima b.

**Properties of Proxima b.** The Proxima b's mass is estimated to be  $M \sin i = 1.3 M_E$  at a distance of 0.049 AU, which is 20 times closer than the Earth is to the Sun [1]. The uncertainty in the orbital inclination angle to the line of sight,  $i$ , implies that the true planet's mass can be either comparable to Earth's (Earth-like at  $1.3 M_E$ ) or be a few times larger (4-5 times or a super-Earth planet). For an Earth-like planet, Proxima b's slow rotation rate should not have a significant impact on magnetic field generation, as this is mostly influenced by the internal heat flux that controls the mantle convection rather than a dynamo [2,3] (Christensen & Aubert 2006; Stamenković et al. 2012). Thus, we can expect that the planet has an Earth-like dipole magnetic field. However, if the planet is super-Earth size, full mantle convection becomes less efficient, so that heat in deep interiors is transferred by conduction rather than convection. This reduces the efficiency of volcanic, tectonic activity and the magnetic dynamo in massive terrestrial type planets [3]. Because the secondary atmosphere of exoplanets are formed due to outgassing driven by volcanic and tectonic activity, we cannot expect a thick atmosphere (if any) from this planet.

**Effects of ProximaCen on Proxima b.** Proxima Cen is a red (M5.5) magnetically active dwarf star. The star's X-ray luminosity at the level of Sun's solar maximum, but because it is 20 times closer to its neighboring planet, Proxima b receives 400 times larger flux. Ribas et al. has estimated that the total XUV flux is about 60 times greater than that received by Earth from the Sun [4]. Such large XUV flux from the star ionizes atmospheric atoms and molecules and produces photoelectrons. In [5] we have developed coupled hydrodynamic-kinetic model that describes the upward propagating photoelectrons that outrun ions in the absence of a radially directed polarization electric field and form the charge separation between electrons and atmospheric ions. For ionospheric ions with energies over 10 eV, the polarization electric field cancels a substantial part of the Earth-like planet's gravitational potential barrier, enhancing the flux of escaping ions and forming an ionospheric outflow.

If we apply the derived scaling of the loss rate with  $F_{XUV}$ ,

$$\dot{M} \text{ (in g/s)} \sim 1.6 \times 10^4 F_{XUV} \text{ (in erg/cm}^2\text{/s)},$$

then the escape time of a 1-bar oxygen rich atmosphere on *Proxima Cen b* is expected to be  $\sim 10$  Myr. Thus, radiative forcing should play a crucial role in oxygen ion loss via enhanced ionization and heating of the lower atmosphere, and in the formation of ambipolar electric fields in the upper atmosphere. Steep electron temperature gradients in the upper atmosphere should produce strong ambipolar fields above the exobase, and initiate increased outflow of  $O^+$  and  $N^+$  ions. Also, a recent MHD model of the stellar environment of Proxima Centauri suggests that the close-in Earth-size planet with an Earth-like magnetic moment should be subject to wind pressure of  $\sim 1000$  times greater than that exerted at Earth, compressing the planetary magnetic field, and thus reducing magnetospheric distance by a factor of 3 [6]. Ionospheric electric currents induced by the compressed planetary magnetic field efficiently dissipate energy at the rate of  $\sim 10^4$  erg/cm<sup>2</sup>/s through Joule resistive heating in the polar cap region. Observations of Earth's response to solar wind pressure show that Joule heating at the rate of 10 erg/cm<sup>2</sup>/s significantly modifies the electrodynamics and thermodynamics of the coupled magnetosphere-ionosphere-thermosphere system by increasing neutral and ion temperatures and densities.

### Conclusions.

Our results imply that the combined effects of  $>60$  times enhanced XUV fluxes with 1000 times enhanced dynamic pressure from its host star, Proxima b has a very low probability to be a habitable planet as most of exoplanets found in habitable zones around M dwarfs.

### References:

- [1] Anglada-Escudé, G. et al. (2016) *Nature*, 536, 437; [2] Christensen, U. R., Aubert, J. (2006) *Geoph. J.*, 166, 97; [3] Stamenković et al. (2012). *ApJ*, 748, 22.; [4] Ribas, I. et al. (2016) *A&A*, accepted; [5] Airapetian et al. (2017) Accepted by *ApJ Let.*; [6] Garaffo et al. *ApJ Let.*, 833, L4