EVRYSCOPE DETECTION OF THE FIRST PROXIMA SUPERFLARE: IMPACTS ON THE ATMOSPHERE AND HABITABILITY OF PROXIMA B. W. S. Howard[1] and M. A. Tilley[2], and H. T. Corbett[1], and A. A. Youngblood[3], and R. O. Parke Loyd[4], and J. K. Ratzloff[1], and N. M. Law[1], and O. Fors[1,5],and D. del Ser[1,5], and E. L. Shkolnik[4], and C. A. Ziegler[1], and E. E. Goeke[1], and A. D. Pietraallo[1], and J. Haislip[1], [1]Department of Physics and Astronomy, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3255, USA, wshoward@unc.edu, [2]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA, USA, [3]NASA Goddard Space Flight Center, Greenbelt, MD, 20771, [4]School of Earth and Space Exploration, Arizona State University, Tempe, AZ, 85282, USA, [5]Institut de Ciències del Cosmos (ICCUB), Universitat de Barcelona, IEEC-UB, Martí i Franquès 1, E08028 Barcelona, Spain.

Introduction: Proxima b is a terrestrial-mass planet in the habitable zone of Proxima Centauri [1]. Proxima Centauri's high stellar activity however casts doubt on the habitability of Proxima b. Superflares (extreme stellar events with an estimated energy release of at least 10^{33} erg) and any associated energetic particles may permanently prevent the formation of a protective atmospheric ozone layer, leading to UV radiation levels on the surface which are beyond what some of the hardiest-known organisms can survive, e.g. [2, 3].

The Proxima superflare: In March 2016, the Evryscope array of small optical telescopes [4] recorded the first superflare seen from Proxima Centauri. Proxima increased in optical flux by a factor of ~68 during the superflare and released a bolometric energy of $10^{33.5}$ erg, ~10X larger than any previously-detected flare from Proxima. Over the last two years the Evryscope has recorded 23 other large Proxima flares ranging in energy from $10^{30.6}$ erg to $10^{32.4}$ erg; coupling those rates with the single superflare detection, we predict at least 5 superflares occur each year [5].

Impacts on the climate of Proxima b: We employ a coupled photochemical and radiative-convective planetary climate model to determine the effects of the observed flare activity on the potential habitability of Proxima b [2].

Atmospheric impacts and ozone loss. We use the Evryscope flare rates to model the photochemical effects of NO_x atmospheric species generated by particle events from this extreme stellar activity, and show that the repeated flaring may be sufficient to reduce the ozone of an Earth-like atmosphere by 90% within five years; complete depletion may occur within several hundred kyr [5].

Surface UV Environment. Without ozone, the UV light produced by the Evryscope superflare would have reached the surface with ~100X the intensity required to kill simple UV-hardy microorganisms [6], suggesting that life would have to undergo extreme adaptations to survive in the surface areas of Proxima b exposed to these flares.

We compare the UV surface environment of Proxima b to that of the early Earth, which may have undergone significantly higher UV fluxes during the early evolution of life. Archean Earth climate models give UV surface fluxes on Earth during the pre-biotic (3.9 Ga ago) and early Proterozoic (2.0 Ga ago) epochs [7]. Assuming full ozone-loss, the surface UV-B flux during the Proxima superflare was an average of 2X higher than that 3.9 Ga ago and 3X higher 2.0 Ga ago, although between flares the UV flux was much lower than Earth's, because late M-dwarfs are far fainter in the UV than solar-type stars. The UV-C superflare flux was 7X higher than that 3.9 Ga ago and 1750X higher than 2.0 Ga ago; again, the UV-C flux potentially reaching Proxima's surface is the critical difference compared to Earth's environment [5].

Implications for nearby terrestrial planets: Two-thirds of M-dwarfs are active [8], and superflares will significantly impact the habitability of the planets orbiting many of these stars, which make up the majority of the Galaxy's stellar population. Measuring the impact of superflares on these worlds will thus be a necessary component in the search for extraterrestrial life on planets discovered by the NASA TESS mission [9] and other surveys. Beyond Proxima, Evryscope has already performed similar long-term high-cadence monitoring of every other bright Southern TESS planet-search target, and will therefore be able to measure the habitability impact of stellar activity for these stars.

References: [1] Anglada-Escudé G. et al. (2016) *Nature, 536,* 437. [2] Tilley M. A. et al. (2017) *ArXiv e-prints*, arXiv:1711.08484. [3] Grießmeier J. M. et al. (2016) *A&A*, 587, A159. [4] Law N. M. et al. (2015) *PASP*, 127, 234. [5] Howard W. S. et al. (2018) *ApJL*, in press. ArXiv e-prints, arXiv:1804.02001. [6] Gascón J. et al. (1995) *Curr Microbiol*, 30, 177. [7] Rugheimer S. et al. (2015) *ApJ*, 806, 137. [8] West A. A. et al. (2015) *ApJ*, 812, 3. [9] Ricker G. R. et al. (2014) *Proc. SPIE, Space Telescopes and Instr.*, 9143, Abstract # 914320.