Impact of Stellar Superflares on Planetary Habitability

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High-energy radiation caused by exoplanetary space weather events from planet-hosting stars can play a crucial role in conditions promoting or destroying habitability in addition to the conventional factors. In this paper, we present the first quantitative impact evaluation system of stellar flares on the habitability factors with an emphasis on the impact of stellar proton events. We derive the maximum flare energy from stellar star spot sizes and examine the impacts of flare-associated ionizing radiation on CO_2, H_2, and N_2+ O_2-rich atmospheres of a number of well-characterized terrestrial type exoplanets. Our simulations based on the Particle and Heavy Ion Transport code System suggest that the estimated ground-level dose for each planet in the case of terrestrial-level atmospheric pressure (1 bar) for each exoplanet does not exceed the critical dose for complex (multicellular) life to persist, even for the planetary surface of Proxima Centauri b, Ross-128 b, and TRAPPIST-1 e. However, when we take into account the effects of the possible maximum flares from those host stars, the estimated dose reaches fatal levels at the terrestrial lowest atmospheric depth on TRAPPIST-1 e and Ross-128 b. Large fluxes of coronal X-ray and ultraviolet radiation from active stars induce high atmospheric escape rates from close-in exoplanets, suggesting that the atmospheric depth can be substantially smaller than that on Earth. In a scenario with the atmospheric thickness of one-tenth of Earth's, the radiation dose from close-in planets including Proxima Centauri b and TRAPPIST-1 e reaches near fatal levels with annual frequency of flare occurrence from their host stars. The radiation dose for newely discovered planets, such as TOI-700 d, is indeed smaller as estimated upon the observation.

Keywords: Stellar flare, Ionizing radiation